THE SOCIETY OF

PLASTICS ENGINEERS JOURNAL

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SEPTEMBER, 1958 VOLUME 14, NUMBER 9

How to reduce your mold costs

D-M-E STANDARD MOLD BASES can reduce your mold costs in the design stage . . . during construction . . . and throughout the operation of the mold.

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PRESENTS

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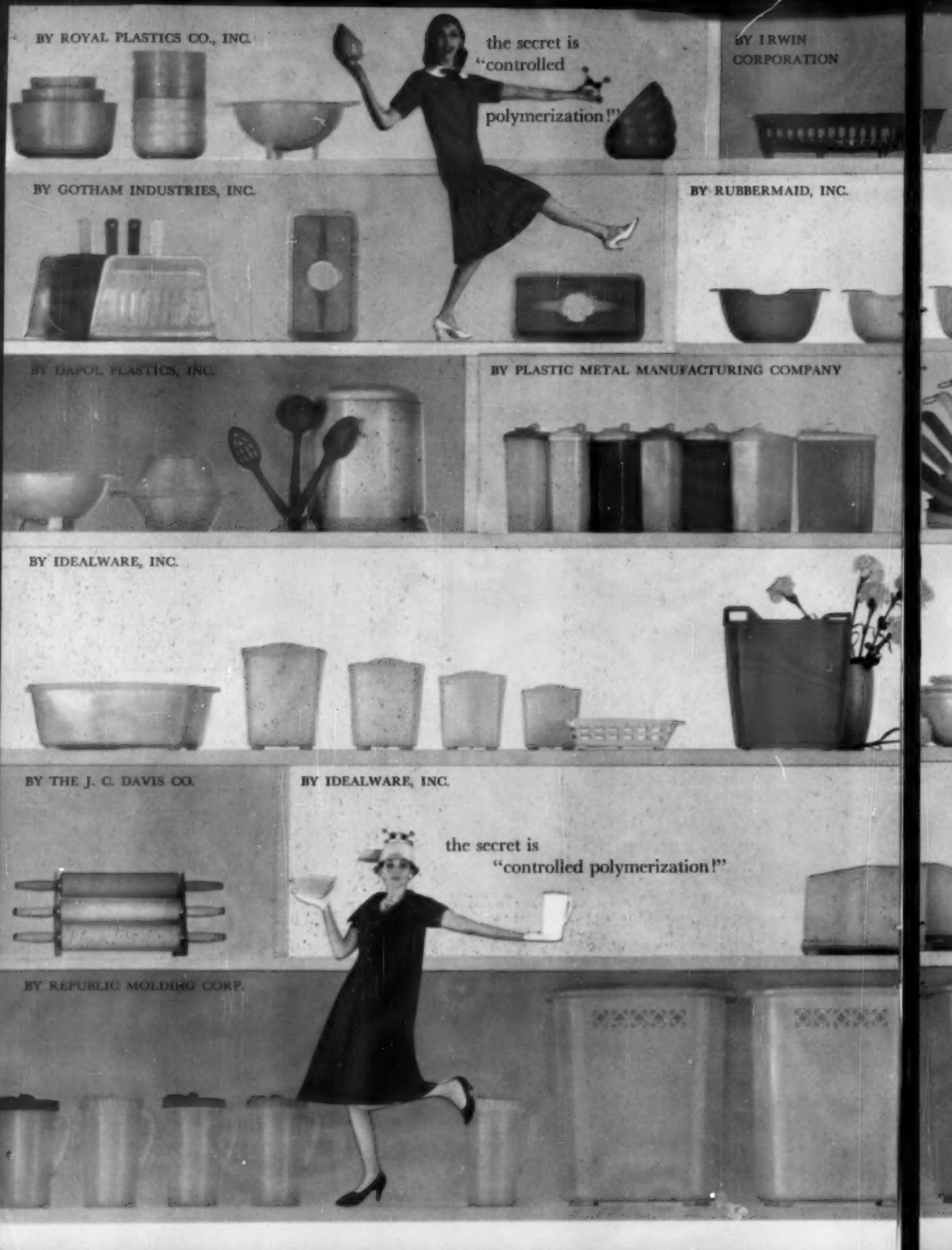
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the secret is "controlled polymerization!"
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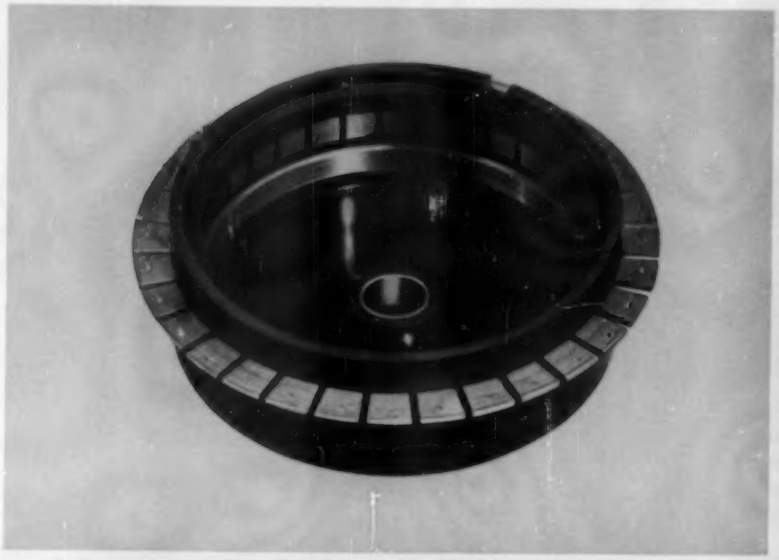

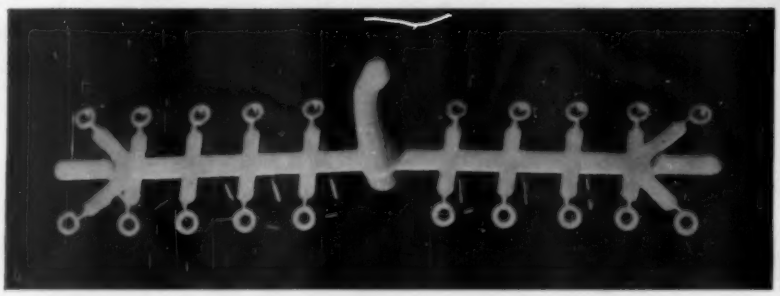

Upper left: 32-station TV switch molded with brass inserts.

Lower left: Insulated tuning core has screw insert.

Above: Insulators for co-axial cable connection.

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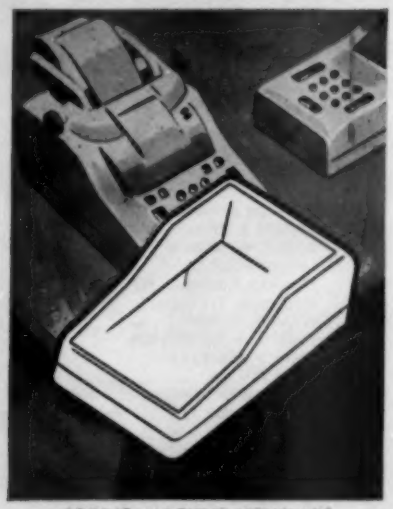

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Charles E. Rhine
Editor

EDITOR'S NOTEBOOK

SPE Co-Sponsors ISO Conferences

SPE members are urged to attend the Eighth Annual Meeting of Technical Committee 61 on Plastics of the International Standards Organization to be held in Washington, D.C., November 3 to 8; and the International Symposium on Plastics Standards and Testing, and meetings of ASTM Committee D-20 and D-9 in Philadelphia the week preceding the Washington Meeting.

SPE is participating more fully in these events than ever before, since they offer many important benefits to our members and since, as co-sponsors, we are contributing financial assistance. SPE National President R.K. Gossett has accepted an invitation to speak at the banquet given during the meeting. Dr. Norman Skow, SPE Intersociety Liaison Chairman for ISO, will be the official SPE representative at the meeting, and your editor will be on hand to bring you a complete technical report of action taken at the meeting to be published in a subsequent issue of the *Journal*.

The technical program is listed below. In addition there will be luncheons, tours, and also special events for wives.

Philadelphia, Pa., Benjamin Franklin Hotel

Oct. 27-29 ASTM Committee D-20 on Plastics.
Oct. 29-31 ASTM Committee D-9 on Electrical Insulating Materials.
Oct. 30-31 International Symposium on Plastics Standardization and Testing sponsored by ASTM for the American delegation of ISO.

Washington, D.C.

Nov. 3 (morning) Plenary Session of ISO/TC 61 at National Bureau of Standards.
Nov. 4-7 Meetings of ISO/TC 61 Working Groups at Willard Hotel.
Nov. 8 (morning) Final Plenary Session at Willard Hotel.

Journal's new Advertising Manager

Leon R. Noe, Jr.

Appointment of Leon R. Noe, Jr., as Advertising Manager of the *SPE Journal* is announced by Thomas A. Bissell, Executive Secretary. Mr. Noe will be responsible for all advertising and sales promotion, including direct representation in the Eastern territory and the establishment of publisher's representatives.

Mr. Noe was previously associated with *Plastics Technology* as Eastern Advertising Sales Manager. From 1952 to 1956 he worked in technical sales for the Plastics Div., Celanese Corp.

Graduated from University of Miami in 1952 with a BBA degree, Mr. Noe majored in marketing and advertising. He also attended the Special Courses Division of Newark College of Engineering to further his knowledge of plastics and processing techniques.

The new *Journal* advertising sales organization headed by Mr. Noe replaces the Dougherty Company which has served since 1956 as the *SPE Journal's* exclusive national advertising representative.

If you use or contemplate using Adipic Acid in elastomers, plastics, plasticizers, synthetic lubricants or as a chemical intermediate, we urge you to get a working sample and quotation from National Aniline.

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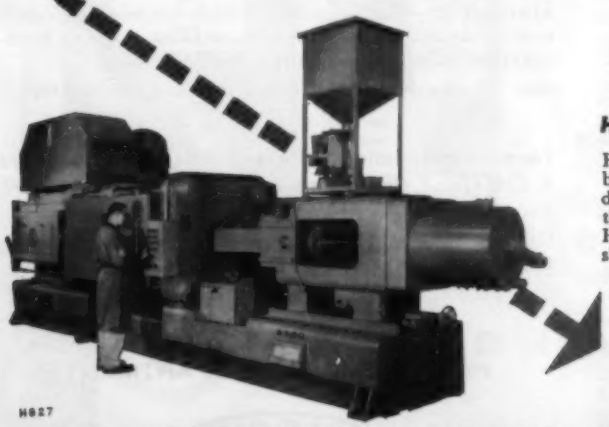

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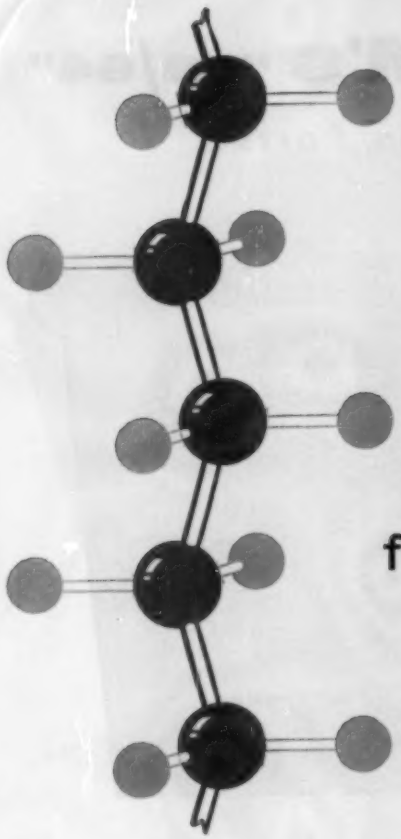

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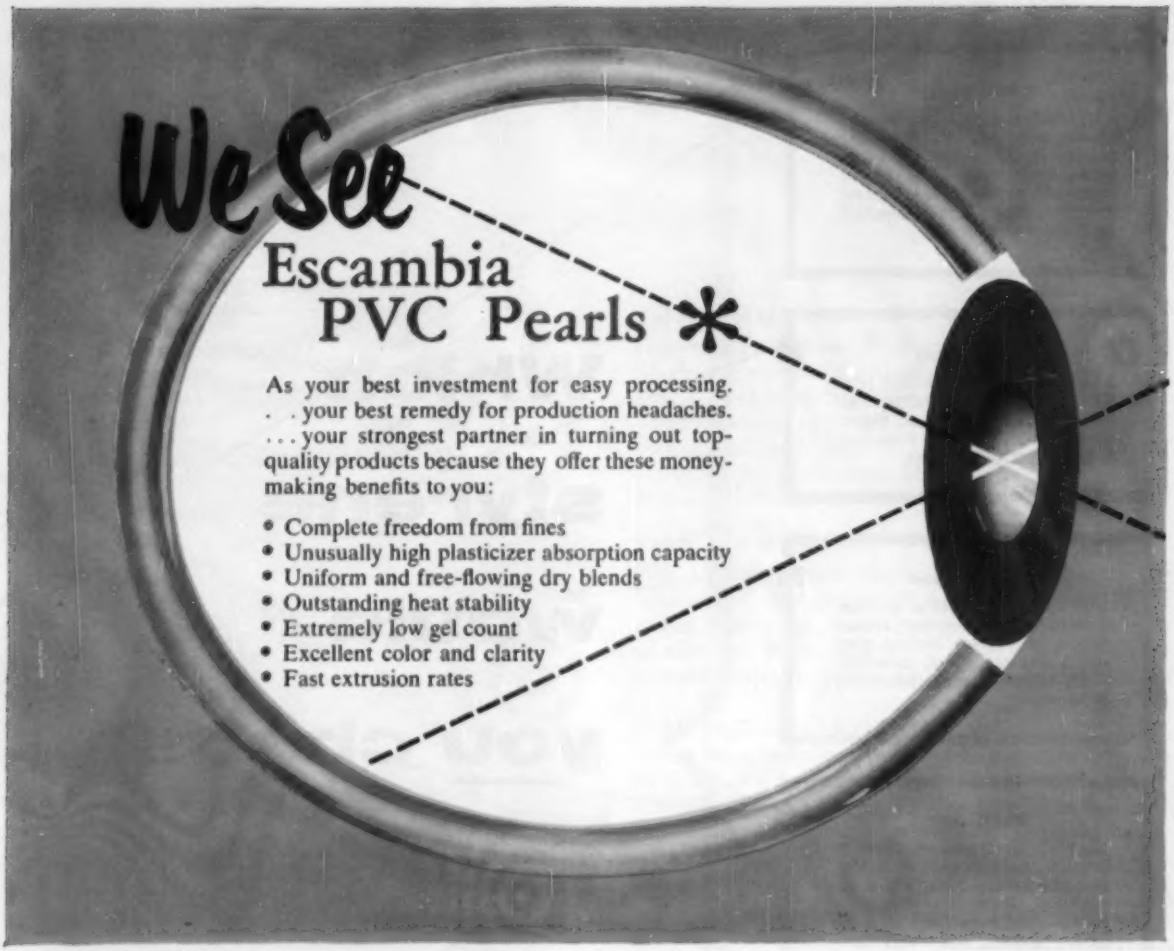
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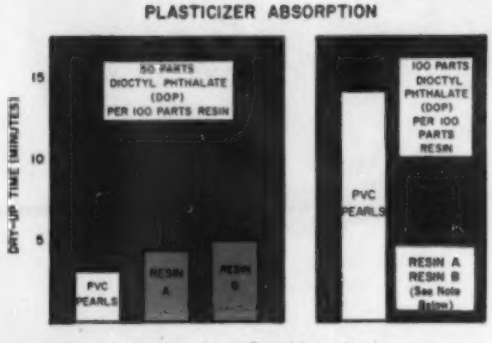

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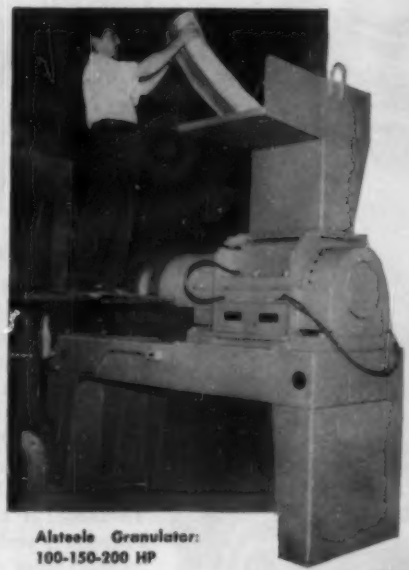

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The Alsteele line of pelletizers works with extruders 2½" to 6" or larger. Instant synchronization with an extruder is made possible by the U.S. Varidrive. And ease of operation, maintenance and cleaning is insured by extremely compact design.

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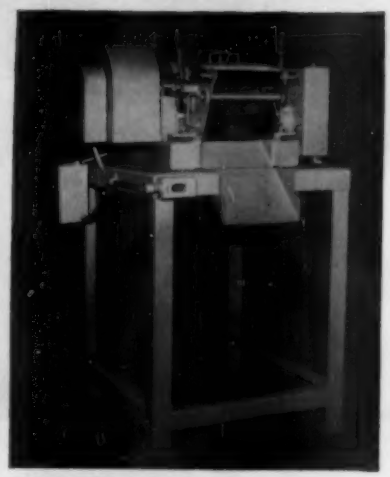

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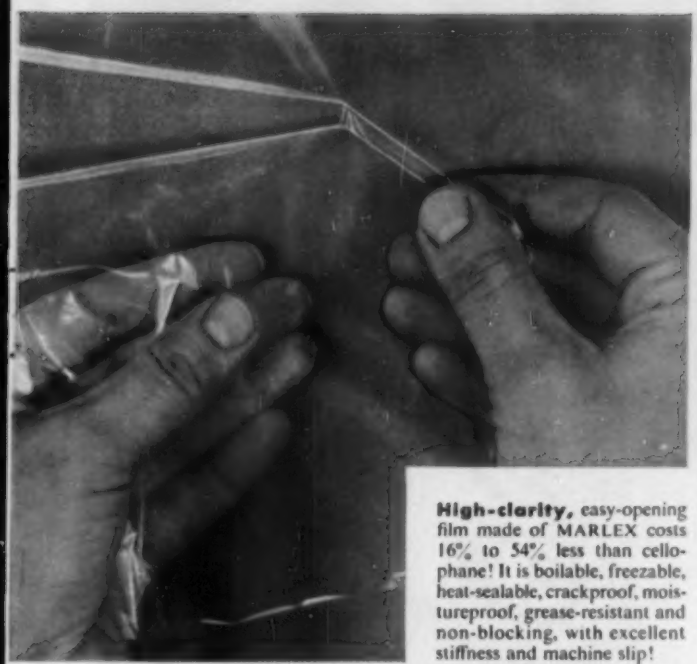
How can MARLEX* serve you?



High-clarity, easy-opening film made of MARLEX costs 16% to 54% less than cellophane! It is boilable, freezable, heat-sealable, crackproof, moistureproof, grease-resistant and non-blocking, with excellent stiffness and machine slip!

Durable and corrosion-proof . . . These attractive, new post lanterns made of MARLEX are really durable . . . won't rust and never need painting! They stand up well in any weather, even in damp salt air or smog!

Light and strong . . . Here at last is a strong, *lightweight*, low-cost marine hawser! Rope made of MARLEX *floats on water!* MARLEX filaments have a tensile strength of 50,000 to 130,000 psi, depending on diameter and drawdown.

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*MARLEX is a trademark for Phillips family of olefin polymers.

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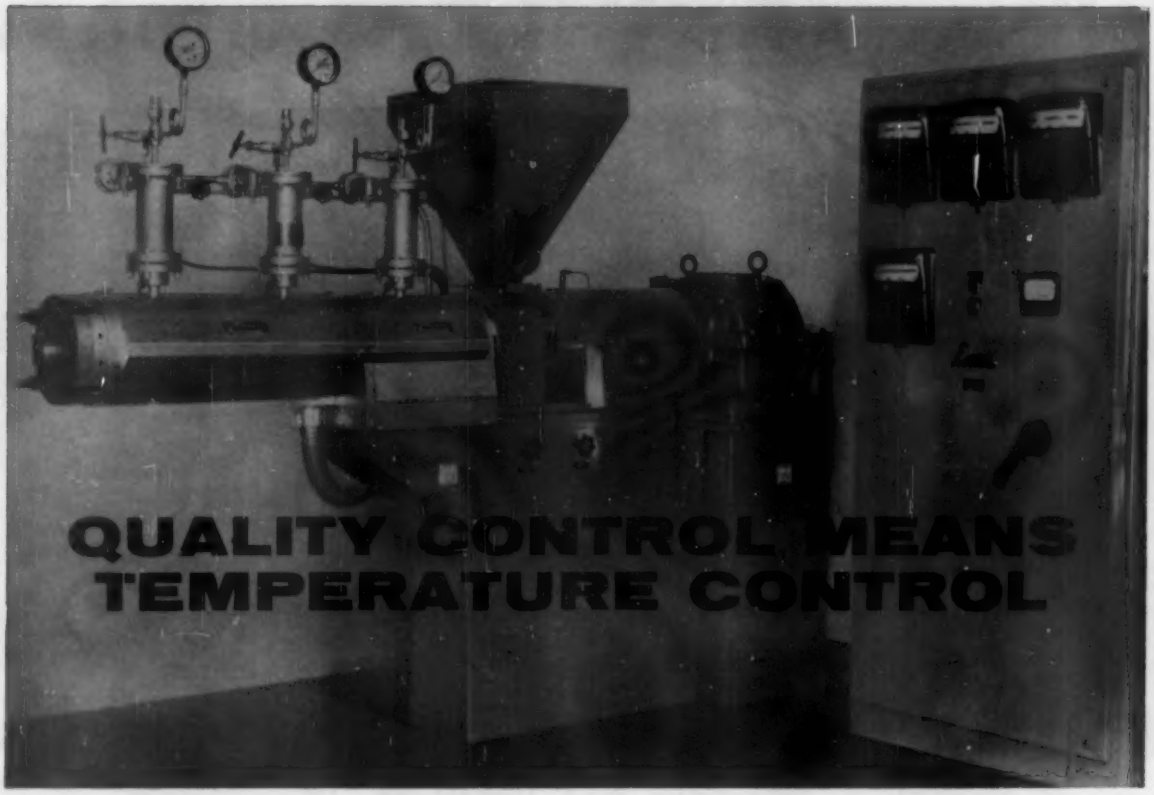

Egan Extruder With "Willert Temperature Control System" Automatically Eliminates Temperature Variations

Heating the plastic material in the extruder cylinder, whether by conduction, induction, or friction, is no problem — assuming the designer has provided sufficient heating capacity and a properly designed screw.

However, provision for efficient dissipation of excessive heat is essential to make any temperature control system complete.

The Willert System is the ultimate in complete control! Excessive heat is removed automatically without moving parts, and without any manual operation of valves or switches by the operator. As a result, closer tolerance extrusions are produced easier and faster.

The Egan Extruder shown above, complete with "Willert Temperature Control System," is available in sizes from 2" through 10". It incorporates standard Egan features such as: herringbone gears, separate heavy duty thrust bearing assembly, complete control panel, wiring, piping, hinged covers for easy access to thermocouples, hopper, screw speed tachometer, and ammeter. Additional features are available.

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Manufacturers of plastics extruders, dies, take-offs, and other accessories

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A long, trouble-free life is the forecast for electrical parts protected with RCI EPOTUF epoxy resins. Insulation made with these resins and appropriate hardeners is tough enough to surpass the most rigorous electrical and mechanical demands. Room temperature curing means no heat of reaction to harm delicate components.

Elements encapsulated, embedded or potted in EPOTUF epoxy resins are virtually free of failure, thus minimizing the need for costly maintenance and increasing the overall efficiency and reliability of the complete unit.

EPOTUF resins harden with outstanding adhesion to metals, glass, ceramics and other materials. They offer high mechanical strength and superior dielectric properties. The liquid nature of these resins permits penetration of fine crevices, and their low shrinkage assures highest dimensional stability.

If these numerous advantages of durable, dependable, corrosion-resistant EPOTUF epoxy resins fit your application, get in touch with RCI.

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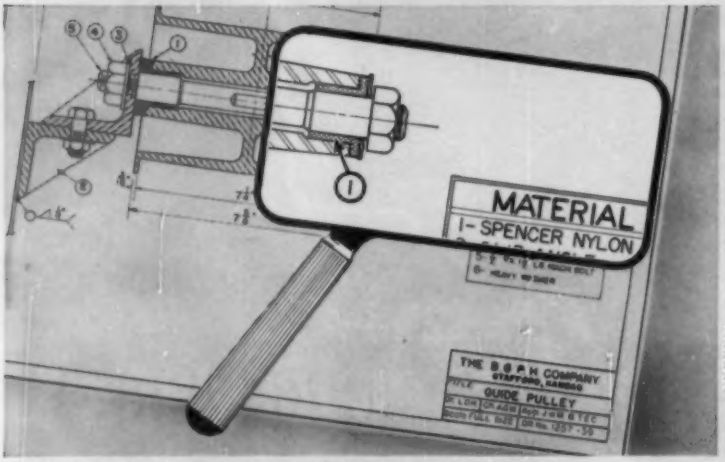
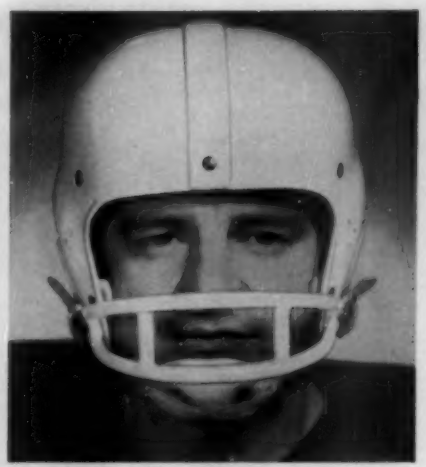


Here is a typical engineering application of Spencer Nylon, a bearing application. Because Spencer Nylons absorb shocks that shatter many other plastics and metals, they are often ideal for use in bearings, valves, and other high speed parts. For example, Line Scale Co. of Oklahoma finds pipeline valves of Spencer Nylon hold up under speeds that would pit brass. And, when one side gets worn, you can turn it over and use the other side.



More flexible than old-type nylons, Spencer Nylon 402 makes possible the easy-fitting Marietta football face guard. Metal-tough, even thin guards give good protection. Yet Spencer Nylon (density 1.14) has less than half the specific gravity of aluminum.

Reports from 4 manufacturers:

"Why I Specify SPENCER Nylon":

Special properties of SPENCER Nylon often outmode metals and other plastics . . .

Specific Spencer Nylons have properties that other materials, including old-type nylons, don't have. In recent months these special properties have won many assignments for engineering applications, and enthusiastic praise from satisfied users. Here are some of the reasons why:

"Spencer Nylon outperforms other nylons in gear applications," says Molding Jobbers, Inc., of Minneapolis. "The first nylon we tested failed under tension. But Spencer Nylon 401 ran as high as 90 ft. lbs. in a torque load test requiring 60 ft. lbs." Another important advantage in gear applications is the fact that nylon is largely self-lubricating.

In tough situations—such as in a connection for pumps and tanks—R&K Tool and Die Company finds that pipe fittings made of high impact plastics sometimes give way under vibration strain. Metal is objectionable on the grounds of expense and corrosion. But pipe fittings made from Spencer Nylon 401 are completely satisfactory.

Pounds instead of ounces! Because processability of Spencer Nylon is superior to that of old-type nylons, it is now possible to make far larger injection-molded pieces. Broad molding temperature range assures proper cavity fill and ease of control.

Also, Spencer Nylons are unaffected by most solvents and dilute mineral and organic acids, allowing for a wide range of uses.

You, too, may find that the special properties of one of Spencer's wide range of nylons offers a better solution to your materials problem. For complete information write: Spencer Chemical Company, 505 Dwight Bldg., Kansas City 5, Mo.

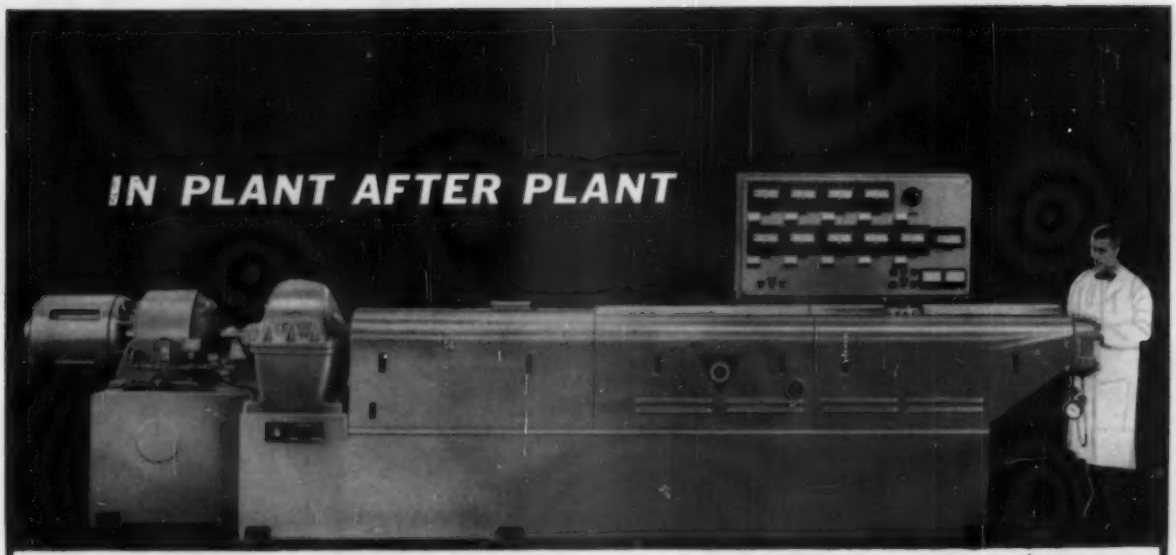
"We couldn't burst-test Spencer Nylon 401 pipe fittings," reports R&K Tool and Die Co. of Cleveland. "Our testing apparatus gave out first." Extra toughness of Spencer Nylon makes it ideal for pipe fittings. Also, Spencer Nylon can be milled, drilled, taped, turned, cut and otherwise machined.

"Far easier to mold than the first nylon we tried," says Ray Hodges, molder of nylon wheel bearings. "Cycle time is decreased, and we get fewer rejects." And Spencer Nylon 401 cuts materials costs 70%. Also, the "give" in Spencer Nylon enables it to overcome minor inaccuracies in alignment not possible with steel.

SPENCER NYLON

SPENCER CHEMICAL COMPANY
General Offices • Dwight Building
Kansas City 5, Missouri

SPENCER



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PRODEX EXTRUDERS with VENT and VALVE L/D 24:1 and 30:1 outperform others in these jobs:

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Package installations for sheet, film, pipe, wire and cable; continuous compounding and laminating. PRODEX EXTRUDERS are available in 1¼", 2½", 3½", 4½", 6" and 8" sizes

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The Inquiring Mind at Oldsmobile

no. 5 OF A SERIES

LIGHTING YOUR WAY TO A SAFER FUTURE

Safeguarding lives is the aim of Oldsmobile's new electronic headlamp aiming device that makes sure every Oldsmobile has perfect "see-ability".

Night driving safety depends upon how precisely headlamps are aimed. Minute errors in adjustment can mean the difference of several square feet in light area on the road. To be completely on the "safe side", Oldsmobile aiming standards specify that lights be aimed *twice* as accurately as required by state laws.

To make certain that every light is aimed perfectly, Oldsmobile engineers developed an ingenious electronic device that effectively measures light intensity and direction, even at Oldsmobile's highest production rate.

On the assembly line, every car is automatically shuttled to the aiming platform where two probes rise out of the floor and "feel" the exact location of the car. The "eyes" of the aiming device then align themselves with the centerline of the car. A series of photoelectric cells instantly record the light intensity and direction on large dials. A built-in scanning circuit then inspects all settings of the headlamps to make certain they are accurate. If there is an error, a colored soap solution is automatically sprayed on the windshield, and the headlamps are re-aimed.

Oldsmobile takes pride in producing an automobile as advanced in every respect as modern technology can make it. However, you owe it to yourself to have your headlamps periodically checked. As part of General Motors' public-spirited "Aim to Live" program, your Oldsmobile Dealer is featuring headlamp aiming, as well as other important safety services for you. Stop in soon . . . and while you are there, take a test drive in a new Olds—sales leader of the medium price class.

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PLASTICS ENGINEERS JOURNAL

Volume 14, Number 9, September, 1958

Breakthrough in Polymer Technology

Dozens of industrial, academic and consulting laboratories are discovering how to make large molecules with ever more regular structures. With skill and speed, technologists are transmuting pure research into production on an impressive scale.

Irving Skeist, Ph.D.
Consultant
Skeist & Schwartz Laboratories, Inc.

ACCORDING to the new rules for polymerization of olefins, the simplest structure is the best. Even polyethylene, plainest of polymers, has been pruned of its branches and made more normal. Unsymmetrical monomers such as propylene and isoprene are likewise constrained to polymerize linearly (without branches); but in addition, the polyisoprene is all *cis* and head-to-tail, as in natural rubber, while the polypropylene is isotactic, with each methyl substituent in the same relative position as its predecessor.

These three polymers, in their newly conforming configurations, are about to make history—polyethylene in plastics, polyisoprene as "synthetic natural rubber," polypropylene as the long-sought low-cost synthetic fiber.

There are other isotactic polymers, also: polystyrene, polybutene, *cis*-polybutadiene, and copolymers in variety. And in addition to isotactic polymers, in which the substituents are all carbon atoms with mixed *d* or *l*, it is posible to make syndiotactic polymers, with alternating *d* and *l*.

These stereospecific polymers were first observed in this country by Schildknecht and coworkers in polyvinyl ethers, a decade ago; but it remained for Ziegler in Germany and Natta in Italy, as well as Phillips and Standard-Indiana researchers here, to discover the well-ordered polyolefins. Heart of the process, always, is some kind of complex metal catalyst. The old-style free radical or soluble ionic catalyst starts the chain and then leaves the growing polymer molecule to fend for itself. The complex metal catalysts, on the other hand, shepherd each new monomer molecule into place. The neatness of polymer structure shows up in sharper X-ray diffraction patterns, indicating crystallinity, higher softening and melting temperatures and greater strength.

Among polymers with carbon-oxygen backbones, too, the accent is on simplicity, symmetry, linearity. The para-phenylene group, having done so well in epoxy resins and glycol terephthalate fibers and films, is getting a new workout in the polycarbonates. Delrin, Du Pont's acetal resin, is presumably polyoxymethylene from formaldehyde, while Hercules' Penton is a symmetrical chlorinated acetal derived from pentaerithritol. Professor C. C. Price of the University of Pennsylvania has made an isotactic, optically active polymer from propylene oxide.

Thermosetting resins and rubbers continue to follow a trend toward wide spacing and even distribution of cross-links. In epoxies, polyurethanes, and now synthetic rubbers, the linear intermediate resin is terminated at both ends by reactive groups, so that the entire length of the intermediate molecule is utilized when these groups are cured. Tying the loose end results in more even stress distribution, hence better physicals than in "old-fashioned" thermosets.

Growing Pains

For most of these precocious infants, the future looks bright; but the plastics industry as a whole is suffering growing pains. What is worse, many of the plastics seem to be settling down to the pace of Gross National Product.

Old plastics never die, and rarely fade away. For a plastics sales manager, however, to do no better than Things in General is a fate worse than death.

The cellulosics and phenolics reminisce from their rocking chairs, in which they undergo considerable movement without getting very far. Cellulosics have lost to slush-molded vinyls for much of the doll body business, and were saved from destitution by women's shoe heels. But blister packaging may help sheet sales. Celanese plans a strong push for 0.88 mil cellulose acetate, "the breathable film," in prepackaging of vegetables and meat. The photo film business continues to grow; and modern decor demands a colored butyrate or propionate telephone.

The rumble of jet planes through the sound (and heat) barrier is music to the ears of the phenolics; among moderate-priced plastics, they stand the heat

This paper was presented before the Association of Consulting Chemists and Chemical Engineers, Inc.

best. For structural purposes, they are reinforced with glass or asbestos; for bonding aluminum and other metals, they are alloyed with epoxies. Shell molding and the bonding of wood waste are still promising outlets for the phenolics, but slow to develop.

Amino resins have made progress as bonding and adhesive resins—urea for plywood, melamine for the decorative facing of phenolic laminates. Melamine dishware continues to benefit from imaginative styling and quality molding; elsewhere, they have lost ground. Plaskon, junior to American Cyanamid in molding powders, has increased capacity and expects to sell more urea-formaldehyde to be preheated electronically for large moldings such as toilet seats and TV cabinets.

The methacrylates enjoy a structure free from sensitive tertiary hydrogens, so that transparent polymethyl methacrylate sheets and moldings can be used outdoors without ultraviolet degradation, while the higher alkyl methacrylate polymers impart long-lasting improvement to the viscosity index of lubricating oil. A methacrylate-based auto finish promises longer life, though at higher cost. Rohm and Haas has introduced a tough methacrylate copolymer and a transparent polyester-styrene-methacrylate resin for glass-reinforced plastics. While Du Pont is encouraging the reinforcement of methacrylate with synthetic fabrics and glass fiber, Hercules and I.C.I. have postponed their joint venture in methacrylate.

In acrylate esters, Celanese will utilize Goodrich know-how to compete with Rohm and Haas and Carbide. To many users, acrylics have become synonymous with quality for outdoor latex paints. While agreeing with other vinyl acetate paint base makers that the right vinyl acetate copolymer does as good a job at a lower price, Celanese has decided to "jine 'em" instead of trying to "lick 'em." The acrylates are growing fast, and could spurt ahead of vinyl acetate if the price becomes comparable.

Nylon 6, Allied's caprolactam polymer, is making slow progress in the extreme-toughness applications dominated by Du Pont's nylon 66, polyhexamethylene adipate. All the nylons are threatened to some extent by low-pressure polyethylene and other newcomers; but the prospects for nylon 6 still look good enough to entice Spencer and Foster-Grant, who will polymerize Allied's monomer. The new nylon is potentially cheaper than the older varieties. Foster-Grant, with its integrated molding operation, is in an excellent position to solve the finicky processing problems that have been hindering utilization. With the aid of German monomer know-how, Foster-Grant may become as integrated in caprolactam as it is in styrene.

Styrene polymer is perched uneasily on a rocky plateau to which it climbed two years ago, after a sensational twenty-fold rise in the previous decade. For a brief time, in 1952, it led the thermoplastics; but vinyls and now polyethylene have overtaken it. Although there is cheerful talk of growth prospects in disposable packaging and indoor lighting fixtures, it appears that molded styrene polymers will continue to yield to polyethylene for housewares and toys, while vinyl acetate and acrylic creep up on styrene-butadiene paint latex. And the export market, like plastics export markets in general, is drying up.

A transparent high-impact styrene copolymer could improve the styrene picture greatly. Styrene-acrylonitrile copolymers, though difficult to mold, are gaining adherents because of their improved resistance to heat and solvents. Tough terpolymers of styrene, butadiene and acrylonitrile are being extruded into more miles of pipe and sheeting.

Cyanamid's methyl styrene homopolymer and copolymer with acrylonitrile are at last in production and offer better heat resistance in the same price range as their styrene counterparts, with lower gravities.

The methyl styrene, from acetylene and toluene, contains 33% of the rotation-hindering ortho isomer which is credited with raising the heat distortion temperature.

When Firestone and Goodrich announced plans for greatly increased production of GR-S rubber, mostly 75/25 butadiene/styrene, the styrene producers made an "agonizing reappraisal," slashed the price of rubber grade monomer from 16¢ to approximately 12½¢/lb., dissuaded the rubber companies from building their own monomer plants. Polystyrene from the four majors is now down to 24¼¢. In the blunt idiom of the price list, "no trespassing" signs have been posted on both monomer and polymer.

In vinyl chloride, the price cuts were too late and perhaps too little to stop the staking of claims by new prospectors. At 25¢ or even a few pennies less, PVC is still attractive. Many producers are expanding. In addition to several integrated companies, mostly film and sheeting calenderers, Escambia has come on stream with polymer, while Allied is doubling monomer capacity and Ethyl has its monomer plant ready. A scramble for business, with downward pressure on prices, seems in the offing.

Once again, vinyls are on their way to beat last year's figures by a substantial amount. Floor coverings, mostly asbestos-vinyl tile, are already sharing the market on an even basis with the cheaper "asphalt" tile (which contains no asphalt). Protective coating uses, especially on metal, are growing rapidly, as are molding and extrusion applications. Film is making progress. Plastisols are finding wider markets for slush molding as well as for foams. The acquisition of Elastomer Corporation by Bakelite presages a big expansion in vinyl foam and sponges. Rigid PVC pipe, conveniently bonded with solvents cements, should come into more widespread use where corrosion resistance is needed, as the resin technologists overcome their difficulties.

Vinyl acetate producers are happy with the flow of their fruity liquid into adhesives, latex paints, textile sizes and vinyl chloride copolymers. One producer looks forward to an industry total of 20 million gallons of vinyl acetate-based latex in 1958. Total for all latex paints, including the heavily predominant styrene-butadiene, was only 55 million gallons in 1956.

Economizing auto makers have replaced polyvinyl butyral side- and rear-window sandwiches with tempered glass. But Monsanto and duPont are taking their case to the public, may get the butyral restored.

The Younger Thermoset

Three younger thermosets are hoping to break into the select nine-figure group by 1960. Polyesters now in their teens, are closest to the goal. The epoxies, scarcely of school age, are advancing rapidly, while the infant polyurethanes are trustfully expecting an Alice-in-Wonderland expansion in foams.

Chemically, all three have this in common: they are two-stage resins in which the intermediate polymer is a linear or near-linear molecule of controlled length and composition. This makes it possible to build in properties surpassing those of phenolics and amino resins, in which the molecules branch out in all directions from the very beginning. In the world of plastics, the older cross-linking resins are the atom bombs, while the newer ones are the controlled energy sources.

Photo courtesy of Allied Chemical Corp.

Two pounds of urethane foam poured into the cavities at each end of this glass fiber reinforced polyester guide boat make it virtually unsinkable. After curing overnight, the excess foam is trimmed off with a saw or knife.

Polyesters

Honor without profit is the fate of the polyesters. These are the combinations of glycol maleate-phthalate with styrene and the polyallyls that are usually reinforced with glass fiber to produce a variety of glamour items: boats, corrugated translucent panels, radomes, ducts for aircraft, housings of complex shape. Leisure-time America is taking to the water, and the care-free polyesters are riding the crest. If we are to believe the statistics, the polyesters grew an amazing 28% in 1956, will show another whopping gain for '57. But neither the resin suppliers nor the fabricators are living it up.

Chief difficulty is the low investment required to make or use a polyester. At least a dozen companies make substantial amounts of resin, and estimates of the total number of producers run from 50 to 140. At the fabricator end, the situation is even worse. The larger items are made by custom lay-up procedures that squander man-hours. Estimating is too often haphazard. The industry is badly in need of industrial-chemical engineering services to streamline techniques, develop combinations of materials and methods that will provide the most functional properties per dollar.

Permix molding, in which a glob of resin, fiber and filler is compression-molded, is one of the techniques that offers the most promise.

Epoxies

With epoxies, the outlook is refreshingly rosy. The resin suppliers have done an outstanding development job. Although epoxies are double the average cost of all plastics, their usage grows by something like 50% each year. Excellent adhesion to metals and glass, low shrinkage on cure, ability to cross-link without application of external heat and without emission of volatiles, high tolerance for fillers, toughness—these are the charms that awaken the enthusiasm of the most blase buyers.

With the brashness of quiz kids, the epoxies offer answers to a great variety of problems. Two-thirds of the resin still goes into the first well-developed end-use, chemically resistant primer coatings. But other applications are leaping ahead—tooling for the aircraft and automobile industries, potting and encapsulating of electrical components, adhesives, solders, patch compounds. Filled with sand, epoxies provide skid-resistant coatings for asphaltic concrete roads. In this highway-building, safety-sensitive land of ours, an application like this could out-distance all others by many miles, if it gets rolling.

Epichlorohydrin, key to present-day epoxies, is held by Shell, Union Carbide, and Dow. The first two now share the epoxy resin market with Ciba and Jones-Dabney. Dow is certain to be a strong challenger.

Carbide's peracetic process for making epoxide intermediates from diolefins promises to provide cheaper epoxies in the future. Hundreds of compounds have been evaluated, and several look good.

Polyurethanes

The polyurethanes, imported from Germany just a few years ago, expanded their way to some ten million pounds of flexible, semi-rigid and rigid foam. At densities usually below 3 pounds per cubic foot, that's a lot of foam. Profits should have made a pleasant tinkling sound; instead, there was a dull thud as some of the weary pioneers shut their doors. At fault was excessive feedback, that old bugaboo of communications in market research. Optimistic voices had fallen on receptive ears, were amplified into echoes louder than the original signals. Foam capacity was crash-programmed to 100 million pounds.

Until recently, flexible as well as rigid urethane foam was based on polyesters with two or more terminal hydroxyls. Now the polyether glycols are taking over. Du Pont's Teracol is presumably the tetra-methylene polyether-diol from tetra-hydrofurane. Carbide and Dow offer polypropylene glycols with predominantly secondary hydroxyls, while Wyandotte gets the more active primary terminal hydroxyls by block-polymerizing polypropylene glycol with ethylene oxide. These propylene oxide derivatives are only half the price of polyester polyols based on adipic acid. Moreover, they, as well as Teracol, produce foam with stress-strain behavior closer to foam rubber, hence are more suitable for cushioning and mattresses. Once again, the air-packagers are sure that a nine-figure volume is just a couple of years away. It can't come too soon for the companies who have built large plants to produce TDI and other isocyanates.

Meanwhile, back on Madison Avenue, the motivation researchers have good things in store for the rigid and semi-rigid foams. M.R. has already put to profit its discovery that men want cars that are masculine—Really Big—fueled from Towers of Power delivering More Strength Than Your Car Can Handle. That urge to dominate sells plastics, too—longer bodies take more enamel, oversize fins require bigger tail lights using more methacrylate.

Now these latter-day disciples of Freud have re-explored his teachings, find new lodes of gold in our ambivalences. We want to be protected, too. In the auto of tomorrow, we'll get vicarious virility *and* the security of our infant and earlier days. Rigid and semi-rigid crash pads, sun visors and side panels will reassure us against the buffets of a hostile world, as we sink into the enveloping embrace of individually molded flexible foam seats.

The auto industry, again, is the largest potential customer for urethanes without holes. Urethane tires have

Photo courtesy of Celanese Corp. of America

High density polyethylene goes into housewares, bottles and containers, toys, appliance part, monofilaments, pipe and industrial components.

outstanding abrasion and wear resistance, may become especially useful for heavy duty on trucks and busses. Easy processing is being built into them through the use of unsaturated polyesters and polyethers, which can be vulcanized with peroxides as well as sulfur-accelerator combinations. Other improvements, still under wraps, promise to give better building tack, compatibility with other rubbers, and temperature resistance.

Polyolefins

The climax of our plastics story, this year and for many years to come, stars the polyolefins. Polyethylene is far and away the fastest growing plastic—too fast, some fear. Polypropylene is being researched freneticall-ly by a dozen large companies as both a plastics and a fiber. Synthetic rubbers, virtually monopolized by butadiene, are moving toward isoprene and isobutylene.

Only five years ago, Bakelite and Du Pont were the sole U.S. companies converting ethylene gas to translucent, waxy pellets. Now there are a dozen. Capacity doubles every few years; this is surely the growth plastic of our decade.

How are the producers making out? Old hands are having no trouble. But some of the neophytes are complaining of aching backs from technical snafus, sore throats from futile huckstering. Rated capacity, even on conventional polyethylene, is at least a hundred million pounds over production. Yet Bakelite, Du Pont and U. S. I. have enough confidence in the growth of conventional polyethylene to continue expanding.

The most encouraging aspect of the polyethylene situation is the continuing increase in the use of film. Self-service of groceries has been such a success in the supermarket that it is being extended to soft goods and all the glittering miscellany of the variety stores we once called "5 and 10's." The 1½ mil polyethylene bag is the preferred method of prepackaging.

Polyethylene film is also becoming more important in farming and construction—lining irrigation trenches and wooden forms for pouring concrete, covering freshly poured cement, replacing glass in greenhouses, keeping out the rain while the house is going up, and laminated to kraft or aluminum foil as a permanent vapor barrier. Small wonder that resin producers and film extruders seek the mutual security of "going steady."

Another important plus-factor in the future of conventional polyethylene is that considerably lower prices will encourage wider usage.

Now comes the new, oriented, low-pressure, high-density polyethylene. Koppers, Phillips, Hercules, Celanese, Grace are already offering products from their own reactors; many others will follow. By next year-end, there will be well over a billion pounds of conventional and new polyethylene capacity.

"Will I be happy, will I be rich?" asks the child in the song; and the mother coos, "What will be, will be." Less complacent about the future are the sales managers who must sell or eat the coming bumper crops of high-density polyethylene. To some extent they will invade the territory of other plastics, especially conventional polyethylene, vinyl, and high impact styrene. Beyond that, they must work up new markets based on the high heat resistance, modulus, strength and solvent resistance of their material. Pipe is one of the fields where conventional polyethylene has excelled; the higher burst strength of the new varieties should help them here. Also, if they can get free of the catalyst fragments that are so detrimental to electrical properties, they can expect to take over important markets from vinyls.

Isotactic polypropylene is already in production by Montecatini and Hercules. Made by the same heterogeneous catalyst techniques as linear polyethylene, it is under consideration by most polyethylene producers. Some oil companies may skip polyethylene altogether. enter the plastics field with the C-3 polymer.

Isotactic polypropylene is stiffer than linear polyethylene, has higher tensile strength. Melting at 160°C, it has promise as both a fiber and a plastic. A possible defect is its rather high brittle temperature range, only slightly below O°C, which rules it out for many military applications.

Other olefins may also be polymerized with heterogeneous catalysts to give isotactic structures. Carbide and Dow researchers find a wide variety of properties, spanning the whole polymer range from elastomers to fibers, according to the nature of the side chains. The

Photo courtesy of Dow Chemical Co.

Expanded polystyrene is the basic of a new perimeter and cavity wall insulating material.

methyl side chain has already been discussed. Normal side chains of six to eight carbon atoms have a plasticizing action, give rubbery materials with melting points almost as low as natural rubber. On the other hand, some of the shorter branched side chains are capable of stiffening the polymer, raising the melting point to 300°C or even higher; and all this is in an aliphatic hydrocarbon! Some of these polymers must have commercial utility.

The olefin homopolymers (derived from a single monomer) afford a vast selection of characteristics; the copolymers offer even more. When two or more kinds of repeat units are present in a polymer, the properties are not necessarily the weighted average of the respective homopolymer properties. The copolymer tends to be less ordered, softens at a lower temperature, dissolves in more solvents, processes more readily. Vinyl chloride-acetate coating resins, acrylic fibers, and all the cellulosics are thermoplastics making use of the copolymerization tool, while polyesters, butyl rubber and ion exchange resins based on styrene-divinyl benzene are among the best examples of thermosets in which the copolymerization technique is utilized to give a controlled amount of cross-linking.

Several groups are working on thermoplastic olefin copolymers, and at least one company has made a cross-linkable liquid resin suitable for casting, with price possibilities in the olefin-styrene range.

Non-hydrocarbon monomers, though higher in price than ethylene and propylene, may be incorporated to provide an occasional spot of polarity—a place for attaching water, dyestuffs, printing inks.

Synthetic Rubbers

In polymer science, there is but one world; sectional boundaries are obscure, and no passport is needed to travel from plastics to rubbers to adhesives to fibers to coatings. In the '40's, polystyrene and the rest of the plastics industry benefited from war-born know-how in GR-S. Now the balance of trade is reversed; the new techniques for mono-olefin polymerization have been applied to the dienes with startling success. Important developments have come from the laboratories of Firestone, Goodrich, Goodyear, Phillips, Esso, Indoil and Aries.

Natural rubber linear, head-to-tail, all-*cis* polyisoprene, GR-S, until recently the best general purpose synthetic, is a butadiene-styrene copolymer with side chain and trans-vinylene linkages detrimental to processing, elasticity and strength. Only God can make a tree, but chemists have now turned out a reasonable facsimile of the latex of the Hevea species. All-*cis* polybutadiene is another significant achievement.

Heterogeneous catalysis is also giving us new ozone-resistant rubbers. In butyl rubber, isobutylene is copolymerized with a few percent of isoprene—just enough to provide an occasional site for vulcanizing. Resistance to degradation is due to the scarcity of double bonds. Now, isobutylene can be replaced by mixtures of ethylene, propylene, 1-butene and/or 1-pentene; some of the vulcanizates appear to be more resilient than butyl rubber.

Delrin

Next to the carbon-carbon bond, the ether linkage is currently getting the greatest attention from polymer scientists. Flexibility at low cost is its chief virtue in the atactic polypropylene glycols of approximately 2000 molecular weight that promise so much for polyurethanes.

The higher atactic polymers of propylene oxide are themselves interesting as elastomers, while the isotactic polymers, made by heterogeneous catalysis at the University of Pennsylvania and Dow, show the high degree of crystallinity that suggests fibers as well as plastics.

In epoxies, the ether linkage provides both flexibility and superior chemical resistance. In Hercules' Penton, a chlorinated polyether of pentaerithritol, high heat resistance is added to these virtues, but at a cost that limits the resin to specialty uses.

Now Du Pont has announced Delrin, which it describes as an "acetal" resin. Delrin also is tough, solvent-resistant, and resistant to deformation under moderate loads at 100°C—a critical temperature because of the many end uses for which "boilability" is desired. A partially crystalline resin melting at 175°C, it is naturally translucent. Even its high gravity—1.425—is suggested to be a virtue, making it "hefty and solid".

Introductory price will be under $1/lb. It is proposed for gears, shafts, blowers, bearings, housings, hardware.

It is generally believed that Delrin is polyoxymethylene, prototype of all polyethers, made from formaldehyde. Polyoxymethylene has been with us a long time; but earlier resins contained impurities which resulted in degradation on heating. Thorough purification of both monomer and polymer according to MacDonald's U.S. Patent 2,768,994, may explain the excellent stability of the new material.

Polycarbonates

A promising new class of polymers, the polycarbonates, has been undergoing intensive development at General Electric, Bayer, and Eastman. Like the glycol terephthalates (Terylene, Mylar, Dacron), the polycarbonates are saturated linear polyesters with a high proportion of paraphenylene groups to make them heat-resistant. They differ in the location of the aromatic group; in terephthalates, it is in the di-acid, while in polycarbonates, it is in the diol portion of the ester.

Another difference is even more important; raw material cost is lower. One of the most likely resins can be made by esterification of bisphenol A with phosgene, should sell eventually for well under $1/lb.

Bisphenol A, the condensation product of acetone and phenol, is the same diphenol that has done so well for the epoxies and some of the unsaturated polyesters. Monsanto, Dow and Shell are producers.

General Electric, looking first to the market it knows best, sees this heat-resistant thermoplastic in all sorts of electrical applications; coil forms, insulating parts, appliance and electronic parts, telephone accessories, heating apparatus, batteries. In addition to good electrical properties, General Electric's Lexan has unusual impact strength—over 12 foot pounds per inch of notch—combined with sufficient hardness so that a pencil of it may be sharpened to a point and driven through a wooden board with a hammer. Although it is a carbonate, its aromatic content makes it insensitive to water. Heat distortion temperature is approximately 140°F, unusually high for a thermoplastic, and well above vinyls, nylon, fluorocarbons or even Delrin.

The Heat's On

Repeatedly this review has emphasized the improvement in heat resistance which the new polymers have achieved by putting their chains in order. Linear polyethylene is superior to the branched varieties; isotactic polypropylene is still better; 4,4 dimethyl pentene polymer beats even these. In the next price bracket come Delrin and the polycarbonates. Still higher in heat resis-

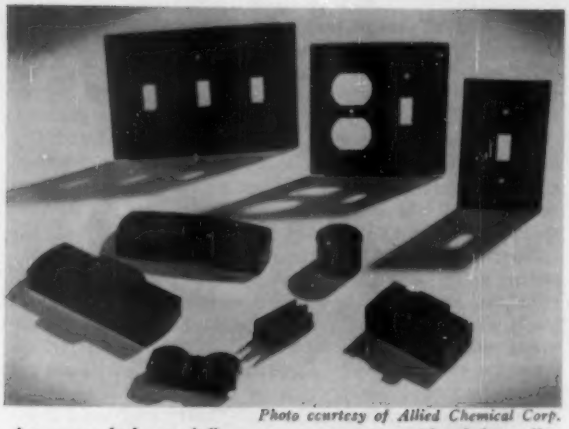


Photo courtesy of Allied Chemical Corp.

An upgraded wood flour urea competes with alpha-cellulose filled ureas in wiring devices and switch plates.

Photo courtesy of Dow Chemical Co.

Injection molded styrene-acrylonitrile copolymers have invaded the plastics dinnerware field.

tance and price, though lower in heat distortion temperature, are the silicones and fluorocarbons.

Much of current exploratory polymer research is devoted to extending the upper temperature limit. Electronic applications call for resins that will maintain good strength and electrical properties when heat and high frequencies gang up on them. Jet planes and missiles demand a kind of stamina that is beyond attainment by the ordinary plastics. Sometimes the difficulties are compounded, as in the case of the radome on a missile, which must have dielectric properties *and* strength at high temperatures *and* the ability to withstand the blows of raindrops, jack-hammering it at supersonic speeds.

In organic molecules, two groups have outstanding resistance to degradation; the carbon-fluorine bond and the benzene ring. Teflon, chlorofluorocarbons, phenolics, terephthalates, bisphenol carbonates make use of these groups to varying degree. Researchers at National Bureau of Standards and elsewhere are trying to combine the two. Poly (tetrafluorophenylene) and poly (tetrafluorophenylene ether) have been produced by ingenious methods, and do show the expected heat-stability; but only low molecular weights have been produced thus far.

But there is a temperature limit beyond which the carbon compounds will not go. The next step is to relegate the organic groups to the side chains, let inorganic linkages make up the backbone of the molecule. Silicones, essentially dimethyl siloxanes, are among the more heat-resistant materials, and can be improved by replacing the methyls with pentafluorophenyl groups.

Even these hybrids have limitations, however. As aircraft climb to working temperatures of 1000°F and higher, it will be necessary to turn to completely inorganic polymers for qualities that cannot be achieved with ceramics or metals.

The silicates are the most familiar of the natural inorganic polymers, useful in the form of asbestos fiber, mica sheet, water glass adhesive. Among the promising synthetics are those based on boron, phosphorus, titanium. Work is proceeding in a dozen laboratories, mostly academic. While many structures have high thermodynamic stability, there is a frustrating lack of kinetic stability in the low- and medium-length polymers made thus far. Sensitivity to hydrolysis is a major problem, for example, with the boron phosphates and the phosphoronitriles. Phenylene phosphates, while lacking the extreme temperature properties of the completely inorganic polymers, are less sensitive to water.

Some inorganic polymers have useful attributes other than heat resistance. The sulfur polymer, of course, is the original cross-linking agent. A polymer consisting of alternating sulfur and nitrogen atoms is semiconducting. Crystalline potassium polyphosphates of very high molecular weight have been synthesized by Strauss at Rutgers.

Radiation, Too

The explosion of the atom is having repercussions in polymer science. When a polymer is irradiated, it undergoes both cross-linking and scission. Cross-linking will predominate in polymers with carbon-carbon unsaturation, e.g., most rubbers, and polymers with sensitive tertiary hydrogens, for example polystyrene and conventional branched polyethylene.

General Electric's Irrathene is polyethylene tape which has been under electron bombardment. A cross-linked material, it no longer melts below its char temperature, shows no stress cracking, and has improved dimensional stability, solvent resistance and dielectric properties at elevated temperature. G. E. finds it useful as Class A insulation for motors and generators, and in other electrical applications.

Potential cost of irradiation of polyethylene film is five cents per pound. The treatment can be carried out only after extruding or molding, since the cross-linked material is no longer amenable to processing.

Graft polymerization, as the name implies, is the growing of new polymer chains from various points on an old one. It is a technique used to achieve a desired molecular weight or particle size distribution, or to bring together two monomers that won't copolymerize otherwise. To the modern Luther Burbank, irradiation is a neat way to get the offshoots started.

As initiators of polymerization, gamma, X, beta rays and electrons have advantages over peroxides and other chemical suppliers of free radicals. Where polymer purity is important, the rays can be depended upon to disappear without a trace, like the icicle dagger in the murder mystery. Also, they permit the polymerization, in the solid state, of solid monomers such as vinyl carbazole, fumaric acid, acrylamide.

Radiation, then, is like heterogeneous catalysis, a way to get the polymer started. Preceding even these initiators is the prime mover, the polymer chemist. In academic, industrial, government, and consulting laboratories, he and his coworkers will originate the plastics of tomorrow.

★ ★ ★

REINFORCING EPOXY WITH METAL FIBER

New compositions for tool and dies offer the possibility of unlimited variations in the field of metal-fiber reinforcing and holds out great potential to the reinforced plastics industry as well as the tooling industry.

A. P. Mazzucchelli

Development Laboratories
Bakelite Co.

Part I

This is the first of two parts. Part II will be published in October issue of the SPE Journal.—editor

NEW EPOXY compositions have been developed which utilize metal-fiber reinforcement in such a manner as to extend substantially those advantages presently provided by plastics tooling to the field of metal fabricating. In this field, competition has been forcing more frequent styling changes, resulting in the introduction of more models with less production per model. Each such style change requires tooling, and with mounting costs this requirement is becoming so serious that the very life of many segments of industry is threatened by it. All of this emphasizes the great need for lower cost, faster built tooling.

With the introduction of plastic tooling compounds based on phenolic, polyester, and epoxy resins, many of these problems were substantially solved. Actually, the room-temperature epoxies, because of their well-known advantages, such as superior mechanical properties, exceptionally low shrinkage, and ability to be either cast or laminated, have become most widely used for tooling. They are particularly well established as materials for jigs, fixtures and models, where procedures have already become standardized and where dependable results may be expected. Practical use of these epoxies has also been extended to molds for hand lay-up and bag molding of reinforced plastics parts, while in the area of metal-forming dies, there has been wide acceptance of epoxies for tool-proving, prototype, and low-production draw dies, particularly for the thinner gages of metal.

However, plastics tooling compounds have found less frequent use for medium-production stamping dies, while here has been only isolated use, with "babying," for the high-production dies. For such rugged applications, the properties of current plastics tooling materials have, in the main, been inadequate.

Another area where improvements in plastics tooling have been desirable is that of large castings. Although room-temperature epoxy resins, highly filled with metal powder or other aggregate mineral fillers, can be cast to large sizes, they are relatively weak mechanically. With normal amounts of metal-powder fillers, excessive peak exotherms are encountered, with concomitant high shrinkage and internal strains. Because of their higher heat-distortion point and longer working life, the more heat-resistant epoxy systems are beginning to be used in the tool and die field, but here too, difficulties have been encountered due to shrinkage and brittleness with internal strains. The inherent advantages, however, of heat-resistant epoxies have led to a constant search for improved methods of using them. The new tooling compositions to be discussed in this paper are a result of this search.

By employing metal-fibers as a reinforcement for heat-resistant epoxy resin systems, these investigations show that reinforced castings can be made with abrasion resistance, impact strengths, heat-distortion points, and thermal conductivities greatly in excess of conventionally filled, room-temperature epoxy compositions. The improvement is such that these metal-fiber-reinforced compositions can be used for the more difficult prototype jobs and many medium-run production jobs. In addition, metal fibers bring to such structures a high degree of machinability and a control over exotherm heat which permits epoxy castings of practically unlimited size with low shrinkage.

Basically, investigation has centered around three types of reinforced, heat-resistant epoxy compositions, utilizing three types of metal-fiber reinforcement, namely, steel, aluminum, and combinations of steel and glass fibers. These fibers are incorporated into the resin and cast by a pressure process. To obtain best performance when applying these compositions to tools and dies, a special technique was developed of flocking or spraying a face coat of short metal fibers on the pattern or mold used for fabricating the reinforced casting. Either glass or metal fibers may be used for the body of the casting, but for best results, it has been found necessary that this face coat of chopped metal-fiber

This paper was presented before the 26th Annual Meeting of the American Society of Tool Engineers at Philadelphia, Pa.

flocking be applied to the surface of the casting. In addition to being essential for satisfactory die performance, the metal fibers flocked on the surface prevent the resin face coat from sagging on corners and vertical walls of die molds.

Specifically, the three types of composition which this work indicated to be the most suitable for metal-forming dies and other tooling uses are these: (1) a mass casting of a heat-resistant epoxy resin system reinforced with low-carbon steel fibers of continuous or varying length and surfaced with a face coat based on an epoxy resin and steel-fiber flocking; (2) a mass casting of a heat-resistant epoxy resin system reinforced with glass fiber and surfaced with a face coat based on an epoxy resin and steel-fiber flocking, the face coat sometimes backed with a steel-fiber mat; (3) a mass casting of a heat-resistant epoxy resin system reinforced with aluminum fibers and surfaced with a face coat based on an epoxy resin and aluminum-fiber flocking. In commercial use, these compositions have been designated Epoxy-Alloy ES, EG-SF and EA, respectively.

As a result of extensive laboratory work, a great deal of information on the physical properties of these compositions and the process principles involved in die fabrication has been obtained. The highlights of this work are presented in the next section of this paper. Because of the many possible variations in compositions, the results obtained and the suggestions made should not be considered final. They are simply indicative of the basic principles involved in the area of metal-fiberized plastics tooling and of the practically unlimited range of possibilities they offer. These possibilities can be best exploited by the tool and die industry itself.

Also discussed is a program of field development work by which practical end-use tests were established to correlate laboratory data. Finally, several case histories, drawn from the more than sixty commercial dies fabricated from these new compositions, will be illustrated and analyzed.

Process, Properties, and Variables

As shown in Table I, these new metal-fiber-reinforced compositions provide many improvements over unfilled and powder-filled, cast, heat-resistant epoxy systems. With composition EG-SF, for example, flexural modulus of elasticity is improved from 0.5 to 1.4 x 10^6 psi, and Izod impact strength, from 0.4 to 11 ft.-lb. per inch of notch; while with ES, flexural modulus of elasticity is improved from 0.5 to 1.2 x 10^6 psi, and impact strength from 0.4 to above 1.2 ft.-lb. per inch. This type of composition creates a homogeneous tool or die, so that the danger of bond-line rupture, which frequently occurs between the metal core and resin face coat of a conventional die, is eliminated. It is improved properties such as these which can make possible the extension of plastics tooling to more rugged applications in metal-forming dies.

Homogeneity and metal-fiber reinforcement can also result in a casting with excellent machinability characteristics (Table II) and the unusual characteristic of being magnetic when steel fiber is used. The outstanding toughness which this type of reinforced epoxy displays permits easy retention and support of dowels, screws, and steel cutting edges. In addition to imparting necessary abrasion resistance to the surface of a metal-forming die, the metal fibers flocked on the sur-

TABLE I

Range Of Properties*

Of

A Standard Heat Resistant Epoxy And New Fiber-Reinforced Epoxy Compositions

	Unfilled	Composition-ES	Composition-EG-SF	Composition-EA
Type of Fiber	—	Steel	Glass***	Aluminum
Specific Gravity (D792-50)	1.15	2.25	1.55	1.8
Flexural Properties (D790-49T)				
Ultimate Strength (psi)	17,500	11,000-16,000	16,000-29,000	8,500-13,500
Tang. Prop. Limit (psi)	11,000	6,500-8,300	12,000-25,000	5,300- 7,500
Modulus of Elasticity (10^{-6} psi)	0.5	0.8-1.6	1.4-1.8	0.9-1.9
Compressive Properties (D695-54)				
Ultimate Strength (psi)	33,500	12,500-28,500	21,000-29,000	12,000-21,000
Tang. Prop. Limit (psi)	11,000	6,500-18,500	14,000-20,000	7,500-12,000
Modulus of Elasticity (10^{-6} psi)	0.4	0.4-0.8	1.2-1.8	0.6-0.9
Compressive Prop. @ 200°F. (D759-48) Ultimate Strength (psi)	—	7,700-22,500	16,000-22,000	8,900-14,000
Heat Distortion (D648)°F.	275°F.	>400°F.	>400°F.	>400°F.
Rockwell Hardness (D785-51)	M114	M72-M82	M103-M111	M56-M81
Izod Impact (D256-54T) ft.-lb./in.	0.4	0.8-1.6	11	0.7-1.6
Thermal Expansion Coef. (D696-44)°F.	88 x 10^{-6}	43 x 10^{-6}	—	55 x 10^{-6}
Thermal Conductivity** (Btu/hr./ft.^{2} °F/in.)	2.0	19-30	5	51-131
Maximum Operating Temperature, °F.	—	350°F.	350°F.	350°F.
Water Absorption (D570-54T) 2-in. x ⅛ in. disc-24 hr.	0.16	0.30	0.40	0.35

*Properties measured perpendicular to casting pressure.
**Modified Ingen-Hausz method as described in "Practical Physics" Marsh, White, et al. (1955, McGraw-Hill).
***With steel-fiber face coat.

TABLE II

Comparative Machinability* Of Various Epoxy Compositions

Material	Number of Holes Drilled	Time in Seconds Required to Drill Last Hole
Composition EA	120	6
Composition ES	120	10
Unfilled Heat-Resistant Epoxy	120	6 (severe chipping)
Heat-Resistant Epoxy, Iron Powder-Filled ...	103	300 (severe chipping)
Composition EG-SF	100	300

* By drilling 5/32" holes under constant load into ½" cast and noting drill wear.

face facilitate retention of the face coat on the corners and vertical walls of the die mold during fabrication. (Figure 1)

A wide number of variations, which may have an accompanying effect on properties, are possible in fabricating these materials into tools and dies. Broadly, the fabricating procedure consists of pressure casting a heat-resistant epoxy resin system with metal fibers, or with glass fibers and metal-fiber reinforcement.

Taking a terminal-box draw die for illustration, a typical die of the ES variety would be constructed in the following manner. (Figure 2) A female reinforced mold is first made from a die model. A reinforced wood, or aluminum, mold box extension is then constructed around the mold to hold the fibers in place. A parting coat is applied and a face coat based on a heat-resistant epoxy resin brushed onto the female mold. This resin face coat is flocked with short steel fibers and allowed to become tacky. For small dies, quart-size flocking guns are available; for both small and large dies a metal-fiber-flocking unit especially designed for this application may be preferable.

To cast a solid, homogeneous metal-fiber-reinforced die, such as composition ES, a preweighed, premixed epoxy charge is placed into the mold followed by a preweighed metal-fiber charge. The metal fibers are carefully distributed to give uniform density over the varying contours of the die. The mold-box extension, which is placed on top of the mold box, is three to four times the depth of the desired cast in order to accommodate the bulk of the fibers. A pressure plug is constructed and placed on the fibers in the mold-box extension, forming in effect a closed mold system. The mold is closed slowly, allowing the resin to flow up uniformly through the fibers, with any excess venting through

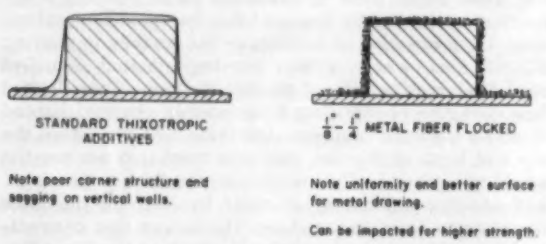
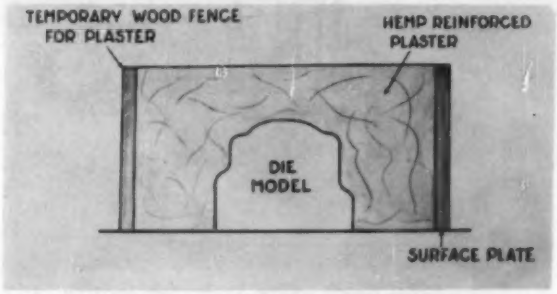
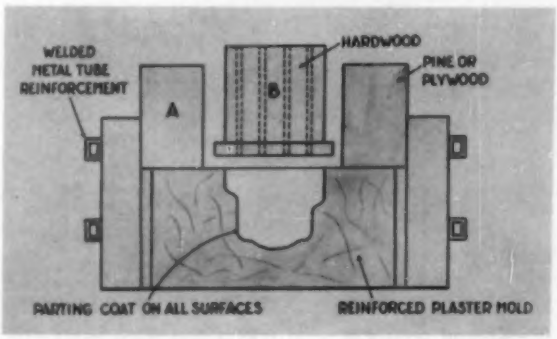

STANDARD THIXOTROPIC ADDITIVES
Note poor corner structure and sagging on vertical walls.
1/8" – 1/4" METAL FIBER FLOCKED
Note uniformity and better surface for metal drawing.
Can be impacted for higher strength.

Figure 1. Advantage of metal-flocked face coat over standard thixotropic additives when using a heat-resistant epoxy system.

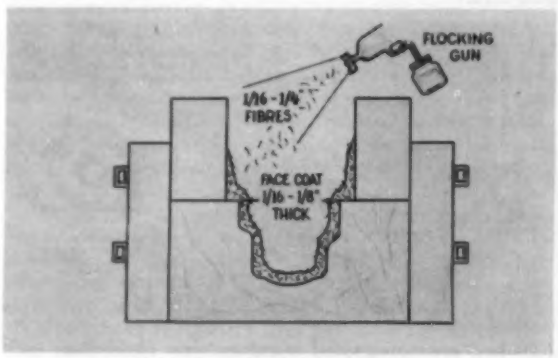
Figure 2. Typical Fabrication Steps for an Epoxy-Fiber Terminal-Box Draw Die



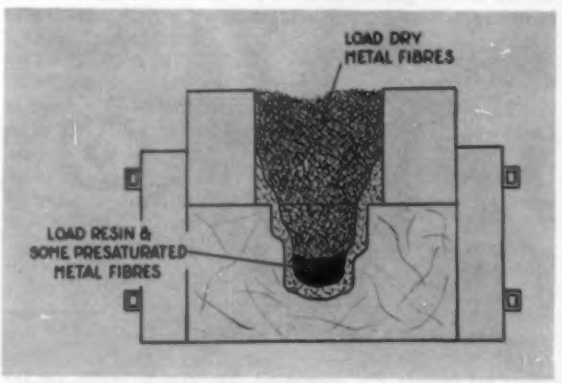
(A) — Make female plaster mold from model.



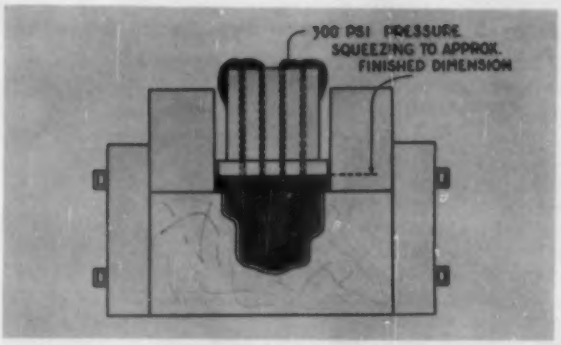
(B)—Construct upper mold-box extension A and pressure plate B, apply parting coat on all inside surfaces.



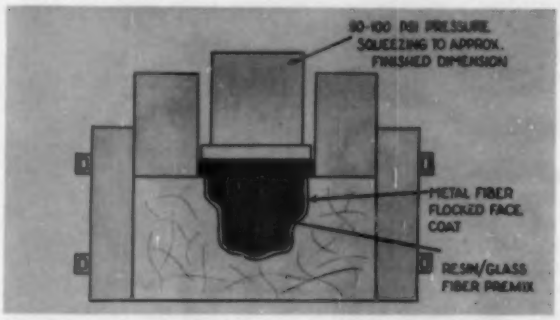
(C)—Apply face coat of resin with brush, spray on flock of metal fibers, allow to gel to tacky stage.



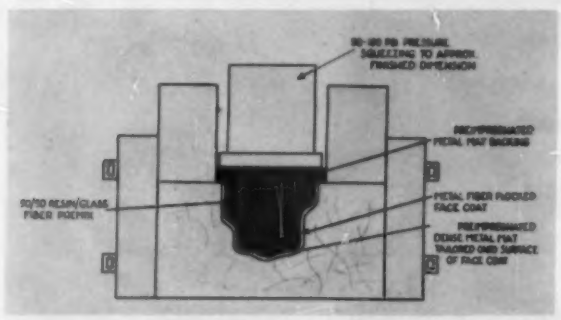
(D) — Loading the mold.



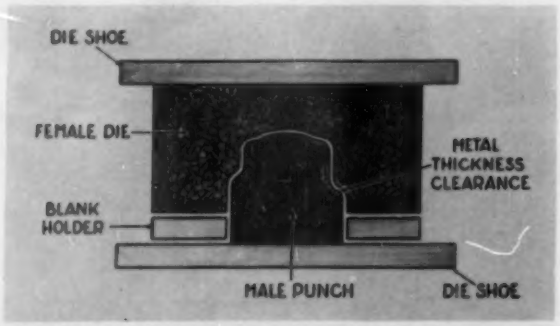
(E)—Pressure-cast punch, allow to harden (approx. 4-12 hrs.), give 2 hr. post cure—300°F.



(F)—Charge premix of resin system and glass fibers over metal-fiber-flocked face coat, pressure-cast punch at 50-100 psi using solid pressure plate, allow to harden and post-cure.



(G)—Lay preimpregnated metal mat on metal-fiber face coat, charge epoxy/glass fiber premix, back up with heavy preimpregnated metal mat, pressure-cast punch at 50-100 psi using solid pressure plate, allow to harden and post-cure.



(H)—Cast female die, mount all components in die set for try-out.

holes in the pressure plug. Using a standard hydraulic press or hydraulic jacks, a pressure of 200 to 300 psi is then applied and maintained until the exotherm developed sets the casting.

The casting is then post-cured up to 300 deg. F. for several hours, depending on size, for attainment of best properties. From a male punch the female would be similarly cast, allowing for part or metal clearance.

Approximately 55 to 60 per cent steel-fiber content is required. The 300-psi pressure has been found to be the most favorable compromise among such factors as optimum properties, available presses, and the physical limitations of mold box and pattern materials. Presaturation of the metal fibers with resin has proved unnecessary.

Because of the lower bulk factor of glass fiber, the wood mold-box extension is only one-half the depth of the casting when this type fiber is used for the mass cast. However, the glass roving must first be presaturated with an equal weight of resin under nominal pressure prior to loading the resin-glass fiber mass into the mold. Pressure casting is then done at 50 to 100 psi using a solid pressure plug, followed by the same curing cycle.

Although not intended for metal-forming dies but for applications taking advantage of its high thermal conductivity, composition EA employs the same general fabrication techniques as composition ES.

As an example of the effect on properties that may be obtained by variations of the above procedure, the impact strength of composition EG-SF rises to over 32 ft.-lb. per inch of notch when casting pressure is raised from 50 psi to 125 psi and glass fiber content from 50 to 62 per cent. Although some strength improvement in castings reinforced with steel fibers is also possible by increasing the casting pressure, this improvement is not so large as to warrant the use of pressures above 300 psi.

Physical properties are also affected by variation in fiber length, with these properties improving as the length of the fiber is increased. However, as fiber length decreases, homogeneity and easier handling are gained. For mass casting, ¾-in. to 2-in. fibers have been found to be the desirable range for the best balance of properties. Very short metal fibers of ¼-in. length are used for flocking the face coat and do not appear to degrade properties seriously, maintaining triple the modulus and about double the impact strength of the unfilled resin.

Recently, densified metal-fiber preforms and mats have been developed for this application and process. Such densified mats of steel fibers are available in densities varying up to 30 per cent steel fiber by volume and in a thickness range of 1/16 in. to over an inch. They can be cut to shape easily with a band saw and can be tailored over patterns. Infiltration of liquid epoxy resin systems into such mats takes place readily by capillary action.

When making a homogeneous metal-fiber-reinforced die, these metal mats or preforms make possible a reduction in the height required for the mold box extension. They are also of advantage for further improving EG-SF dies, where a thin pre-impregnated densified steel fiber mat is tailored against the steel-fiber-flocked face coat, the epoxy glass fiber premix charged behind it, and a similarly impregnated thick mat placed on the top and back of the die. The thin steel mat against the working surface further reinforces the flocked face coat, and ensures uniformity of wear by keeping the glass fibers away from the surface. The heavy mat conveniently provides a more machinable back to the die. (Figure 2G).

Other experimental fibers and fiber forms, such as sintered low-carbon steel mats, which show evidence

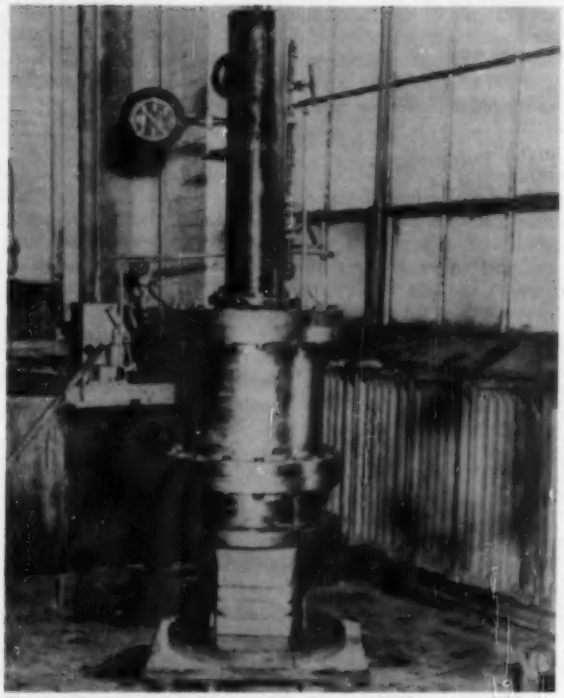


Figure 3. Vacuum-pressure casting unit for metal-fiber-reinforced epoxy dies.

of bringing even better strength properties to these compositions, are discussed in other literature on the subject. (Ref. 1)

A vacuum-pressure process, particularly adapted to all-metal-fiber-reinforced materials, has been used experimentally to minimize any internal porosity which may result in these pressure casts. In this process the resin-hardener system is first de-aerated before injection into the mold system for impregnating the metal fiber. The mold chamber containing the metal fiber is evacuated before applying pressure. While this system requires more elaborate equipment (Figure 3), higher density is achieved with an indication of further improved performance. Such a system also offers the long range possibility of development into an automatic and integrated process.

As mentioned earlier, a heat-resistant epoxy system was chosen as the basis for these compositions because of the advantages this type offers over standard epoxy systems. When reinforced with metal or glass fibers, it greatly reduces galling and creep problems resulting from the low heat-distortion point of room-temperature-curing epoxy systems. In addition to providing the basis for a tool and die material with improved high-temperature performance, such a resin system has the advantage of a longer "pot life" than a room-temperature epoxy.

The use of metal or glass fibers as a reinforcing material reduces the problems of shrinkage and brittleness experienced with most heat-resistant systems and extends their operating temperature to 350° F.

One of the most important characteristics of these compositions, is their mass castability without sacrifice of toughness and other physical properties. The presence of metal or glass fiber reinforcing avoids the excessive peak exotherms, and concomitant high shrinkage and internal strains, normally encountered with metal-powder filled systems. Composition ES has a

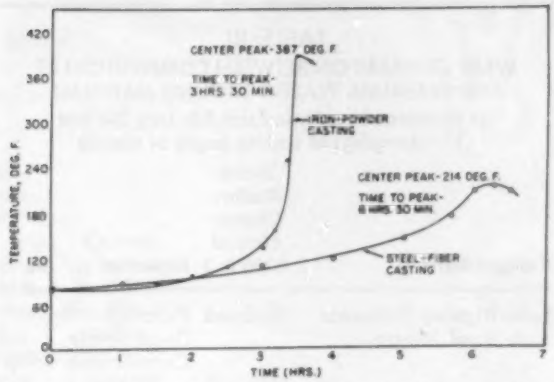


Figure 4. Peak exotherm of steel-fiber-filled versus iron-powder-filled epoxy castings.

thermal conductivity ten times greater than an unfilled heat-resistant epoxy system. Composition EA has a thermal conductivity 60 times greater than an unfilled epoxy and 15 times greater than one containing aluminum powder.

In comparing the exothermic heat of 5-in. x 10-in. x 20-in., heat-resistant epoxy castings, one with 55 per cent iron powder and one with 55 per cent steel fibers, the iron-powder casting reached 387° F., while the steel-fiber casting reached a temperature of 214° F. Gel time doubled for the steel-fiber casting. (Figure 4). Similarly in a 9-in. x 20-in. x 10-in. casting made in an insulated mold and containing 60 per cent steel fibers, peak exotherm reached 311° F. The excellent thermal conductivity and continuous nature of the steel fiber helped to distribute the exotherm throughout the casting, as well as acting as a heat sink. About the same exotherm control was obtained with glass fibers because of their higher specific heat; while aluminum fibers have provided the best exotherm control because of their combination of high specific heat, thermal conductivity, and ability to dissipate heat from the center of the cast.

In this regard, satisfactory castings with low shrinkage have been made as large as 81 in. x 51 in. x 29 in. and weighing 3500 pounds. Shrinkage has varied from practically zero to 0.003 inch per inch, depending on conditions, and averaging 0.0015 inch or less per inch. This compares with 0.010 inch per inch for an unfilled heat-resistant epoxy system.

In the fabrication of tools and dies, the question of whether EG-SF, ES, or EA should be used may arise. Each composition has its own advantages and provides fabricators with a range of choice to meet the needs of specific applications.

Composition EG-SF, for example, offers some fabricating advantages over ES and EA, with extrapolation to complex automotive dies easier at present. Casting pressure required for EG-SF is 50 to 100 psi, as compared with 200 to 300 psi for compositions ES and EA. Mold-box buildup height is ½ the depth of the cast for glass fibers, as compared with a buildup height of three to four times the depth for metal fibers.

These factors generally reduce cost of buildup, press size, and daylight, and minimize pattern and plaster-mold problems. Since a resin-glass fiber premix has mobility under pressure, it uniformly fills out greatly contoured dies. In contrast, available metal fibers show little or no lateral movement during casting, and greater care must be taken in loading in order to obtain uniform fiber distribution. Finally, the mechanical properties of

TABLE III

WEAR COMPARISON BETWEEN COMPOSITION ES AND STANDARD PLASTIC TOOLING MATERIALS

As Measured In A Hydroform Ash Tray Die Test (177 stampings of various gages of metals)

Compositions	Draw Radius Change (Initial 0.156 in.)	Remarks
Low-Rigidity Polyester with Steel Fibers	Failures	Porosity Breakdowns Considerable creep
High-Rigidity Polyester with Steel Fibers	Failures	Breakdowns Fatigue Failures
Medium-Rigidity Polyester with Steel Fibers	Failures	Porosity Breakdowns
Low-Rigidity Polyester with Glass Fibers	0.13	No breakdowns Considerable creep
Room-Temp. Epoxy-Surfaced Aluminum Core	0.05	Initial Radius 0.172 No breakdowns
Composition ES	0.02	No breakdowns

EG-SF are superior to those of the ES and EA. Some of these adverse characteristics of the ES and EA materials and process may be altered favorably by the use of densified metal-fiber mats and preforms. As previously indicated, such mats and preforms will facilitate loading and reduce the mold buildup and casting pressure normally required for composition ES and EA.

On the other hand, compositions ES and EA have some advantages as compared with EG-SF. Greater care must be taken with EG-SF to apply the steel-flocked face coat uniformly and to avoid bridging of the glass fibers in sharp contours. The resin system and glass fibers for the mass must be premixed in a separate operation; whereas, with ES and EA, the mass is directly pressure cast. ES and EA have better machinability than EG-SF and provide materials which are homogeneous, an important characteristic when making die changes or repairs. Thermal conductivity of ES and EA are much better than EG-SF; EG-SF will not heat by induction or resistance as will ES and EA. While the mechanical properties of ES and EA are below those of EG-SF, commercial performance has indicated that the ES and EA compositions are entirely adequate for their particular tooling applications.

Field Evaluations

In the absence of conventional end-use data for correlation with the physical properties of these new compositions, a series of field evaluations were made involving several types of tool and die operations. The results of this work with hydroform dies, draw dies, and vacuum forming dies are discussed briefly below.

In one of the first series of tests in the field-work phase of this program, 6 ash-tray dies (4-in. diam., 1 in. deep) were built and evaluated in a rubber pad press using a 6-in. diameter blank without lubricant. A run of 177 stampings was formed over a 0.156-in. radius using metals such as 0.025-in. and 0.060-in. C.R.S., 0.075-in. S.H. brass, and 0.032-in. and 0.048-in. stainless steel. The results are summarized in Table III and indicate that the ES composition of heat-resistant epoxy reinforced with steel fibers has greater resistance to wear than such standard die materials as a room-temperature-epoxy surfaced aluminum core or a polyester resin and glass fiber pressure casting. Polyester resin and steel-fiber pressure casts made from low, medium, and high-rigidity polyester systems failed in these tests due either to breakdown or excessive creep. (Figure 5) This preliminary work demonstrated the greater latitude provided by a heat-resistant epoxy system as regards toughness and resistance to radius change and breakdowns.

By far the most comprehensive evaluation work was done using a more critical terminal box draw die in which these new materials were compared against current plastics die compositions and processes as well as against iron and a zinc base alloy. A very severe draw die was selected both as regards pressure-casting problems and performance. A 7½-in. diameter circular blank of 20-gage, SAE-1010 cold rolled steel was used to form a 4-in. square commercial terminal box with a 1¾ to 2⅜-in. draw and containing a step or ledge where the stamping was normally trimmed. Pressure casting was considered difficult because of the vertical side walls and inside ledge. The deep draw for the size of stamping, combined with a speed of operation of 600 to 1000 stampings per hour developed temperatures which exceeded 140° F. with the dies varying be-

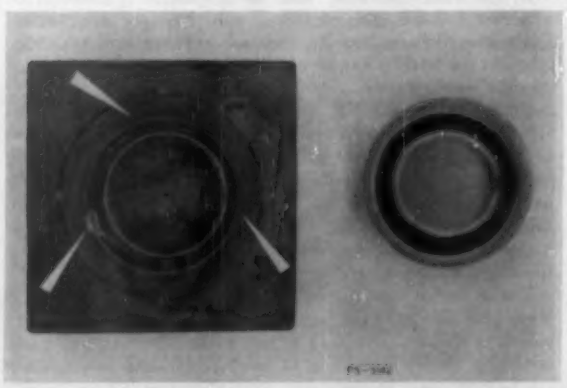


Figure 5A. This high-rigidity polyester/steel-fiber ash-tray test die shows typical breakdowns which occurred after 62 stampings in a rubber-pad press.

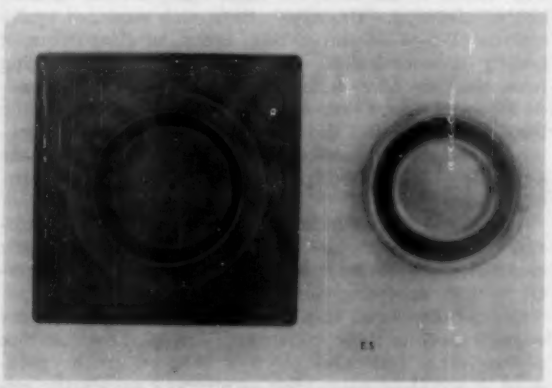


Figure 5B. This ES ash-tray test die remained practically unchanged after 177 stampings in a rubber-pad press.

TABLE IV

Comparison Wear of Terminal-Box Test Draw Dies

Compositions	No. of Stampings 0.038 C.R.S.	Draw Radius Change over Initial 0.109"		Change in inches of Die Size Below Radius over 4" Square	Remarks
		Corners with 2⅜" depth draw	Straight edge with 1¾" depth draw		
Polyester-Glass Pressure Cast (PG)	200	Eroded	+0.06	Not measured	Severe erosion and breakdowns
Room-Temp.-Epoxy Surface Coat on Iron Core (RTESC)	200	+0.12	+0.04	—0.006	Very severe galling and erosion
Heat-Resistant Epoxy-Glass Pressure Cast. Glass Flock Face (EG-GF)	500	+0.05	+0.03	—0.005	Uneven wear, ridging due abrasion
Heat-Resistant Epoxy-Glass Pressure Cast.-Iron Powd. Face (EG-IPF)	1000	+0.03	+0.01	—0.005	Slight uneven wear & ridging. Face coat application difficult
Heat-Resistant Epoxy-Glass Pressure Cast Silicon Carbide Powder Faced (EG-SCF)	1000	+0.03	+0.03	—0.005	Same as EG-IPF
Heat-Resistant Epoxy-Glass-Steel Flock Face (EGSF)	1000	+0.08	+0.01	—0.001	Uniform wear. Face coat application easy
Heat-Resistant Epoxy Steel Fiber-Steel Flock Face (ES)	1000	+0.08	+0.03	—0.004	Uniform wear. Face coat application easy
Zinc Base Alloy	1000	0	—0.01	—0.009	Uniform wear, least erosion but creep & build-up metal flake on radius
Heat-Resist. Epoxy Steel Fiber ⅜" Precision Cast Iron Face (ES-CIF)	1000	0	0	0	No change. Process experimental

tween 115 and 144° F., depending on composition, as measured 0.050 inch from the draw radius at the corners. This accentuated wear and breakdown of the plastics materials permitting rapid evaluation of the different compositions.

A steel blank holder was used, with the die mounted, inverted for operation, in a 93-ton, fast-acting crank press equipped with an air cushion. (Figure 6) Each die was fitted carefully for metal thickness clearance for the most accurate comparison. Durable dies were tested to 1000 stampings, while the poorer dies were stopped after 200 stampings. For lubrication, the same emulsifiable draw-die lubricant was used as for a similar commercial steel die in current operation.

Over twenty dies were made and tested, some of which are reviewed here in detail. Table IV summarizes the pertinent information as regards draw-radius wear and type of wear of the more important die compositions. The dies are listed in the table in general order from poorest to best.

A polyester, glass fiber casting with an iron-powder face coat (PG) was the first composition tested since it represented a type in current commercial use for pressure casting. The die failed very rapidly, showing serious wear, erosion, galling, and breakdown after only 20 stampings. This occurred particularly in the corners of the draw radius and inside ledges. The material was apparently too soft to withstand such a severe test. Figure 7 shows the condition of the die after 200 parts were run.

A polyester die reinforced with steel fiber but with no face coat (PS) showed considerable radius wear and some breakdown due to porosity. It major virtue appeared to be uniformity of wear due to presence of the steel fiber. Here again, the softness of the polyester material appeared to be the dominating factor in giving the poor performance. Testing was stopped after 200 stampings.

Changing from polyester to a heat-resistant epoxy, also reinforced with glass fibers but lacking a face coat, gave no improvement. Rapid and uneven ridging of the die surface developed in less than 100 stampings. The die was repaired in the ridged area to eliminate wrinkling of the stampings, but another 100 stampings developed the same ridging in another area of the die surface and radius. (Figure 8) It was apparent that such rapid failure was due to the abrasion of the exposed glass fibers on the surface.

Adding a face coat of glass flocking to this type die (EG-GF) showed considerable improvement because

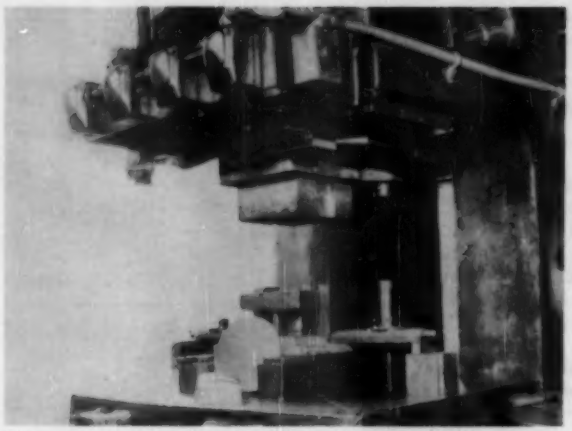


Figure 6. Terminal-box test draw die mounted for operation.

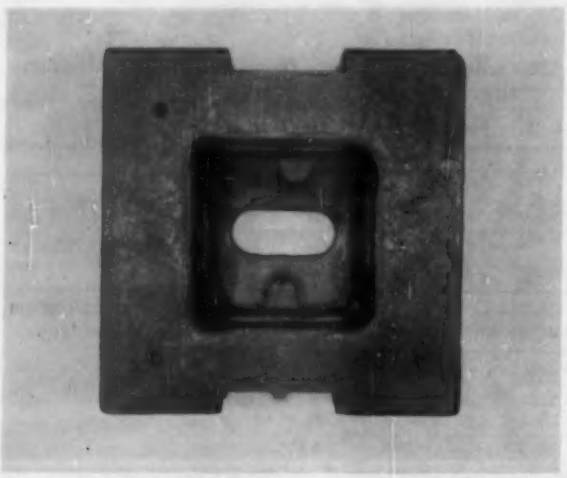


Figure 7. After 200 stampings, a polyester/glass fiber terminal-box test die shows rapid breakdown in draw radius, corners, and inside ledge.

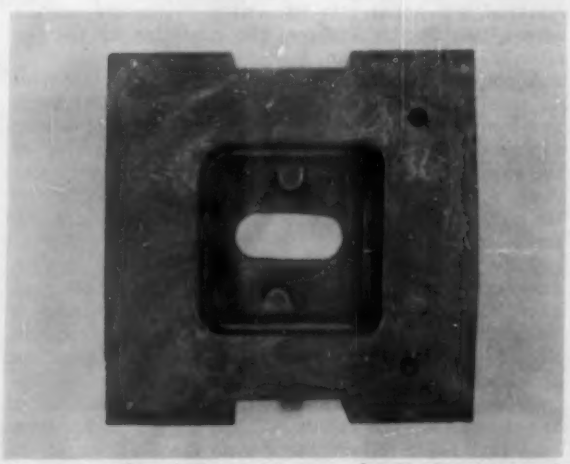


Figure 8. After 200 stampings, a heat-resistant-epoxy/glass fiber terminal-box test die shows severe ridging due to erosion of the glass fibers.

of the better distribution of the fiber on the surface. After 100 stampings, only slight evidence appeared of ridging on the draw radius from abrasion of glass. This became worse gradually, but did not become very severe until 500 stampings had been made. Nevertheless, the poor abrasion resistance on the surface with concomitant ridging of the draw-die radius and surface, plus wrinkling of the stampings, were still considered a negative factor.

An iron core surfaced with a casting of room-temperature epoxy (RTESC), and representing a commercial, prototype tooling product, galled very badly. (Figure 9) Considerable sticking, erosion, and radius wear resulted due to the excessive heat generated during the test. However, there was uniform wear and no breakdowns occurred, which testifies to the virtue of this composition for prototype tooling. Testing was stopped after 200 stampings.

Application of an iron-powder face coat to a heat-resistant epoxy die reinforced with glass fibers (EG-IPF) gave improvement in surface wear as compared with a similar die with a glass-flock face (EG-GF). However, some slight ridging of the die surface became evident after 500 stampings, becoming more general and severe on the draw radius and at the corners when 1000 stampings were approached. Substitution of a more abrasive silicon carbide powder in the face coat of a duplicate die (EG-SCF) gave substantially the same uneven wear and ridging. In addition, the use of metal powder presented process problems, since the face coat was found difficult to apply and hold to the die contours even when normal thixotropic additives were included.

An EG-SF die, a heat-resistant epoxy casting reinforced with glass fiber and surfaced with a steel-fiber-flocked face coat, gave dimensional stability and very uniform wear of the die surface and draw radius over 1000 stampings. In addition, the face coat was much more easily applied. Performance was considered excellent and represented a great improvement over the polyester and glass fiber pressure-cast die and the standard epoxy-glass fiber-surfaced dies.

Composition ES, the heat-resistant epoxy die reinforced with steel fibers and a steel-fiber-flocked face coat (Figure 10), also gave excellent results with regard to uniformity of wear and retention of dimensions.

A zinc base alloy die showed less wear but greater dimensional change than the steel-fiber-reinforced dies. It is interesting that the draw radius of the zinc base alloy die actually decreased in size, due to build-up of metal moving from the die surface. Although all the metal-fiber-reinforced dies tested showed a very great improvement in erosion resistance over previous plastics tooling materials, they were not quite as good as the zinc base alloy die, due probably to their lower hardness. This was reflected in the better-looking stampings, disregarding dimensions, obtained with this zinc base alloy die.

An experimental die (ES-CIF) was made by pressure casting the steel-fiber-reinforced, heat-resistant epoxy composition into a ⅜-in. shell of precision cast iron which served as the working face of the die. The die did not crack or show any significant wear during testing. This represents, an experimental process* designed to lower cost by eliminating the Kellering operation. Building larger dies, however, is required to resolve scale-up problems involved in controlling shrinkage and obtaining a smoother surface. Nevertheless this process offers the promise of lower cost high-production dies. As with the zinc base alloy die, considerable time

* Developed by Modern Pattern & Plastics, Inc., Toledo, Ohio.

was required for spotting and breaking in this die prior to the test run.

In the course of these evaluations, some other general observations were made. Although it was not found possible to duplicate the sharpness of the step in the terminal-box stamping obtained with a steel die, ES and EG-SF gave results approaching those of the zinc base alloy die, giving stampings of greater definition than current polyester or room-temperature epoxy compositions. An ES die withstood the compressive force developed when run 0.080 inch under metal clearance; it cracked when a double blank was intentionally used, but did not fly apart and cause a safety hazard.

Basically, these results demonstrate that the greatest improvement in pressure-cast draw dies is obtained by using a heat-resistant epoxy resin system in place of a polyester resin. For practical success, however, they show that it is necessary to incorporate a fiber filler, such as glass or steel fiber, to provide reinforcement and to control the exotherm and shrinkage in a mass cast. These tests with the terminal-box draw dies also prove the extreme importance of a good drawing surface for the success of metal-forming dies. Glass fibers on the surface abrade rapidly. Powdered fillers, such as iron and silicon carbide powders, appear to erode from the die surface when metal is drawn over it, also inducing abrasion and ridging; whereas, steel fibers on the surface are apparently more firmly anchored and wear uniformly with the resin bond. A steel-fiber-flocked face coat is, in this regard, superior to a face coat of current standard plastics materials.

With the improved performance of ES and EG-SF dies for metal forming, a preliminary study of most suitable draw-die lubricants was considered desirable, since very little work has been reported in this area. A variety of such lubricants was tested by H. A. Montgomery Company, Detroit, Michigan, using a Sliding Friction Test Method (Ref. 2) developed by them, and which involved observing the frictional characteristics of sliding surfaces of composition ES against SAE 1010 C.R.S. and of a hardened tool steel against the C.R.S. This test has been found to correlate with practical experience.

In general, it was noted that the sliding friction was greater when the ES die was used. Coefficient of friction was lowest with dry film lubricants, such as those obtained from blends of alkali soap and polymers in water, variable with nonpigmented and pigmented emulsified compounds, and highest with viscous tacky oils. From these preliminary data, predicted die wear also appeared to be in the same order, namely, from least to most.

The anomalous behavior of the emulsifiable draw-die lubricants on the ES die, from very good to poor, indicates that to obtain best results care must be exercised in their selection. It would be well, therefore, to obtain specific recommendations, based on this test, for the type of metal involved, when long runs are contemplated. In this regard several non-pigmented emulsions, based primarily on alkali soaps with high percentages of fats and oils, have been used satisfactorily. In any event, lubrication of ES and EG-SF dies is not expected to present any greater problem than is normally encountered with metal dies.

Finally, these results indicate that consideration should always be given to the conditioning of a new plastics die. The initial sliding friction on the clean surfaces, which have been freshly lubricated, is frequently twice as high as that observed on tests which are consecutively made without cleaning of the surfaces. Damage to the draw die may therefore occur during the initial strikes because of the much higher friction encountered. Accordingly, the precauton should be taken of swabbing the die surfaces prior to immediate use and also of "inching" the press during the first few stampings.

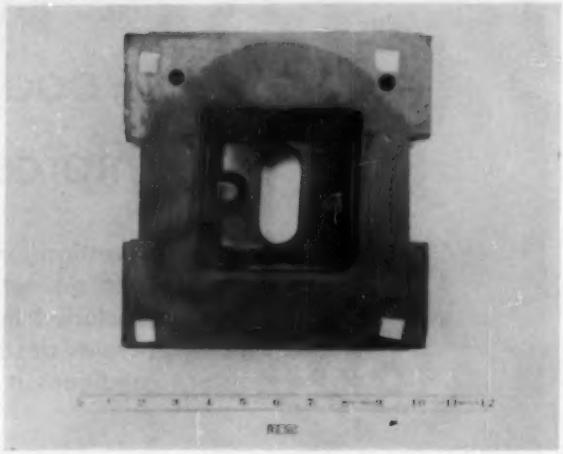


Figure 9. Severe galling and erotion resulted from 200 stampings with this iron-core die, surface-cast with room-temperature epoxy. (RTESC)

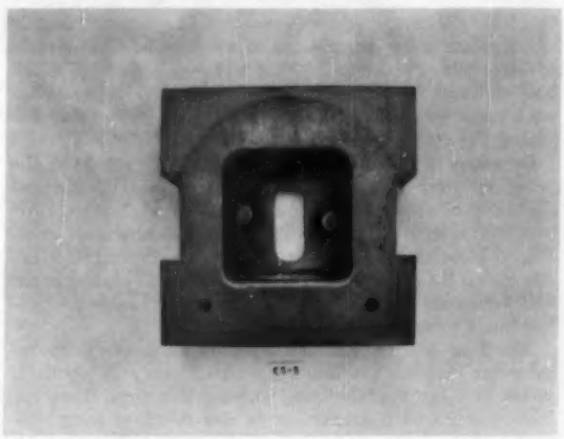


Figure 10. After 1000 stampings, the ES terminal-box test die shows uniform wear.

Careful die tryout is also desirable for location and repair of any minor imperfections caused by occasional porosity, a condition which is minimized by proper fabrication. Such repairs may be made by a simple plug technique.

The effectiveness of composition EA for vacuum-forming molds was also evaluated using a series of test molds used for forming food containers of 0.050-in. impact styrene. A direct comparison was made between composition EA, solid-cast epoxy filled, respectively, with silica, aluminum powder, and aluminum shot, and cast aluminum itself. Composition EA, although not as good as aluminum, gave satisfactory parts at a higher operating temperature than any of the other epoxy molds, indicating that faster cycles would be possible under comparable conditions. Another advantage of composition EA was its greatly superior machinability for drilling vacuum holes.

End of Part I. Part II will be published in the October issue of the SPE Journal.—editor

Protecting Wood from Decay with Reinforced Plastics

A review of the investigations of various public and private organizations on the subject, and a description of a testing program which concluded that a complete covering of reinforced plastics prevents decay in kiln dried wood regardless of the moisture conditions it may be subjected to in service.

Bert M. Zuckerman* and Richard Mark**

THE USE of reinforced plastics in large structures generally leads to design limitations of rigidity, not of strength. Products of this nature, including truck bodies, boats and building panels extensively use sandwich construction to reduce weight and cost while providing the stiffness required.

In many products, particularly boats, wood is the principal core material used. Moduli of rigidity and elasticity of many woods are extremely high in relation to their weights. Over 75% of the commercial reinforced plastics boat builders take advantage of this relationship by embedding wood in the "glass" hulls, decks and transoms in their models to obtain maximum performance in sandwich construction.

Wood as a core material encased completely by reinforced plastics has had a service history of about 15 years in some applications. During this time there has been continued controversy on the merit of such construction from the standpoint of durability. The question was "Will encapsulation by reinforced plastics promote or allow decay of the wood core, or does it protect this core from decay?"

This paper summarizes reports and publications of several agencies pertinent to this subject. Study of these works led to a testing program in which kiln-dried wood covered by reinforced plastics was subjected to conditions designed to approximate long periods of service in an environment favorable to decay.

It must be emphasized that the data and the conclusions concern only wood which is encased on all sides. No protection from decay is insured by the covering of one side only of a wooden structure, and in some cases moisture vapor movement patterns would cause the reverse to be true. The authors also wish to point out that encasement of wood in reinforced plastics to prevent rot is analogous to the galvanizing of iron to prevent rust. Whereas the structure is by no means made quickly useless by breaks in the surface, the efficacy of any structure of this type depends primarily on how well the original covering is applied. Thus, in covering dense species of high expansive strength, laminates of sufficient tensile strength to resist these stresses must be specified to maintain encasement integrity.

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Literature Review

In 1947 and 1949 the US Forest Products Laboratory published one of the first descriptions of testing of sandwich panel durability (Ref. 1,2). These tests included several types of sandwich construction which combined wood and reinforced plastics. Glass cloth and polyester, as well as glass cloth and phenolic, skins were wet-laminated to end-grain slabs of kiln dried balsa. The skins covered only two sides of the sandwich; the edges were either left bare or sealed with aluminized varnish.

The purpose of these tests was to determine the relative suitability of sandwich construction for aircraft, and the results eventually formed a basis for a part of the engineering and design manual "ANC 23 Sandwich Construction for Aircraft" (Ref. 3).

The Supervisor of Engineering Structures Materials, Chance Vought Aircraft, Inc., presented two technical papers (Ref. 4, 5) which included statistical data on the durability of wood-core sandwich after service testing and accelerated exposure to cycles of water immersion, salt spray, sub-zero temperatures and elevated temperatures. The original service testing program instituted by Chance Vought and the results of over 14 years' use of wood-core sandwich constructions provide much valuable data on both metal-faced and reinforced plastics-faced sandwich. However, there is no data included on sandwich panels specifically subjected to wood-decay fungi.

In 1953-54 the Materials Branch, Engineer Research and Development Laboratories, issued two reports on tests of the durability of plywood encased in reinforced plastics (Ref. 6, 7). Specimens were exposed to water immersion and also to direct fungus exposure by means of soil burial in a tropical testing chamber for one year. Flexural strengths and moduli were compared with controls. The average flexural strengths, both for specimens which had been buried in the soil and those which were unexposed (kept on a shelf), were the same at the end of one year. Both types of specimens showed a 10% reduction in flexural strength in aging as compared with the strength of such specimens shortly after their fabrication. Flexural moduli showed no significant changes (Ref. 7).

While these tests did not provide for the specific exposure of the specimens to a recognized wood-decay fungus, decay organisms are generally present in most

soils. The soil block method used here, with the modification that a decay organism is inoculated into the soil, is an accepted means of testing wood treated for fungus resistance.

In December, 1955 the Prevention of Deterioration Center, National Academy of Sciences Research Council, compiled a list entitled "Industrial Fungicides" (Ref. 8). This publication was of interest in this investigation since bisphenol A, one of the common ingredients of epoxy resins, and several metallic naphthenates are listed.

Efforts to learn of the practical effect of the presence of these compounds in resins have been inconclusive. For example, Shell Chemical Corporation states that there is always some free bisphenol A remaining in the epoxy resin as used by the laminator. Thus, some bisphenol A contacts the wood surface on which the liquid epoxy is applied. However, no figures are available as to how many parts per million are present nor how this concentration affects the fungi.

Nuodex Products Company has affirmed that cobalt naphthenate, used as an accelerator for polyesters, has fungitoxic properties; however, its relative toxicity as compared with copper naphthenate, a widely used commercial fungicide, is not known.

A number of companies (i.e. Goodyear Aircraft Corp., Zenith Plastics Co., and the United States Testing Co.) have reported on certain phases of durability testing of wood-reinforced plastics sandwich construction. To the knowledge of the authors such tests have not included exposure of such laminates to wood-decay fungi.

The Bureau of Ships, United States Navy, has been carrying out an investigation which involves several types of sandwich structures, including reinforced plastics and balsa wood combinations, for exposure to sea water under various conditions. These tests are currently in progress and no data is yet available.

Testing The Decay Resistance of Reinforced Plastics-Encased Wood

The experimental program undertaken by the authors was designed to provide controlled laboratory data on the effects, if any, that known wood-destroying fungi have on wood which is encased in fibrous glass reinforced plastics.

As the experiment progressed it became apparent that some of the common resin chemicals were fungitoxic. For this reason a test series was initiated in which rot fungi were subjected to direct contact with some of these resin components.

Wood affected by the advanced stages of decay decreases in dry weight, undergoes changes in color, develops large cracks and shrinks more in drying than sound wood (Ref. 9). It was the purpose of this portion of the test to assay decay as expressed by these criteria in four types of wood or wood-plastics combinations.

Experimental Procedures

The four types of samples used in these tests were: 1) bare wood blocks, 2) wood blocks coated with polyester resin, 3) wood blocks encased in reinforced plastics, and 4) wood blocks encased in reinforced plastics, then drilled to expose the wood, and then patched with resin.

The three principal components of the sandwich laminates tested were balsa wood, polyester resin and glass mat. The balsa wood was chosen as a core because it is commonly used in reinforced plastics boats and also since it contains no extractives within the wood which impart inherent decay-resistance to certain other

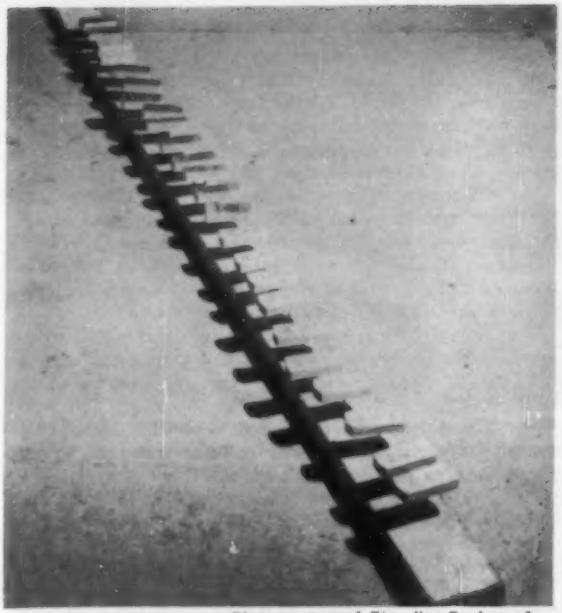

Photo courtesy of Firmaline Products, Inc.

Figure 1. Test specimens of wood coated with polyester resin were prepared by painting the blocks on five sides with room temperature curing resin while mounted on nails; then removing to paint the remaining side.

woods. Polyester resin was selected since it is the major laminating resin used in commercial reinforced plastics, particularly boats. Glass mat was used as a reinforcement since it was felt that the random fibers potentially offered the greatest chance for orifices to occur around the fibers through which the decay fungi might penetrate to the wood within.

Wood blocks were cut from boards of a commercial grade of kiln dried balsa (Grade AL Belcobalsa) and were approximately ½" by 1" by 2¼". Specimens were cut in both end-grain and flat-grain.

Block specimens which were coated with a room temperature—curing polyester resin were first mounted on nails (Fig. 1) and then painted with the following polyester mix:

Parts by weight	
60	Laminac 4116
40	Laminac 4134
3	Cab-o-sil
0.25	Nuodex 6% Cobalt naphthenate
1	Lupersol DDM peroxide catalyst

After the resin had cured, the blocks were removed from the nails, inverted and the nail hole areas painted with the same mix. In some cases complete coverage was not attained and these blocks were repainted to insure a full coating.

Block specimens were encased in reinforced plastics in the following manner:

Strips of glass mat weighing 1 ounce per square foot were cut to an appropriate pattern for enveloping the balsa blocks (Fig. 2). The mat, designated PE-1, had a polyester powder emulsion binder and a #114 finish.

The mat was impregnated with the following resin formulation:

Parts by weight	
90	Polyester PLL-5193
10	Polyester PLL-3136
3	Cab-o-sil
1	Cadet Benzoyl peroxide dissolved in Styrene.

The impregnated glass mat faces and balsa cores were assembled and cured in one operation in heated matched steel dies (Fig. 2). A cycle of 6 minutes at 210°F and 125 psi was employed. At the time of molding the moisture content of the balsa cores was 8%. Upon removal from the dies the specimens were finished by trimming off the circular-shaped flash (Fig. 2).

Weight measurements of the balsa wood cores and the glass mat were taken prior to the lamination. The finished piece weights showed the resin content of the flat-grain blocks averaged 48% of the total weight of glass and resin; that of the end-grain blocks averaged 60% of the total weight of glass and resin.

The finished thickness of the reinforced plastic skins on these laminates was approximately one millimeter.

Holes ⅛" in diameter were drilled in some of the reinforced plastics-encased blocks to expose the wood core. These holes were sealed with the same room temperature-curing polyester resin as was used to coat the polyester resin-encased blocks.

Ten ml. of malt agar (concentration; 45 gms. malt agar per 1000 ml. distilled water) was poured into each decay chamber (Fig. 3). These chambers were capped, then autoclaved at 15 psi for 20 minutes at 250°F and laid on their sides to permit hardening of the agar. This provided a sterile, nutritive substrate in each chamber, into which small equisized segments of inoculum from cultures of wood decay fungi were placed. The decay fungi used in these experiments were *Lenzites saepiaria* and *Poria monticola*. These fungi were chosen because they are recorded as being important causes of decay in wooden boats (Ref. 9, 13). These fungi were incubated at 23°C for two weeks prior to the introduction of the test specimens.

All test specimens were oven-dried until they showed no further loss of water, then the moisture content of each block was raised to at least 30% prior to the inception of the test.

Oven-drying of the bare balsa blocks was accomplished by holding the blocks in an oven at 70°C for 72 hrs. Dried blocks were transferred directly from the oven to an enclosed scale which contained a desiccator, and weighed. Immersion in water for a short period of time sufficed to raise the moisture content of these blocks to a point above 30%. The preliminary weighing and conditioning of the encased blocks was more complex due to the resistance of the laminate to the passage of water. To obtain the oven-dry weight of these blocks it was necessary to dry them for 14 days at 84°C. To raise their moisture contents above 30% required a longer impregnation cycle. Typical absorption rates are shown in Table I.

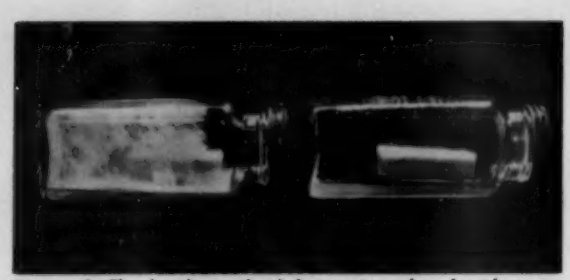

Figure 3. The bottle to the left was inoculated with a rot fungus which has grown from the agar to almost completely obscure the test block. At the right is an uninoculated bottle which contains a specimen used as a check on the experimental procedure.

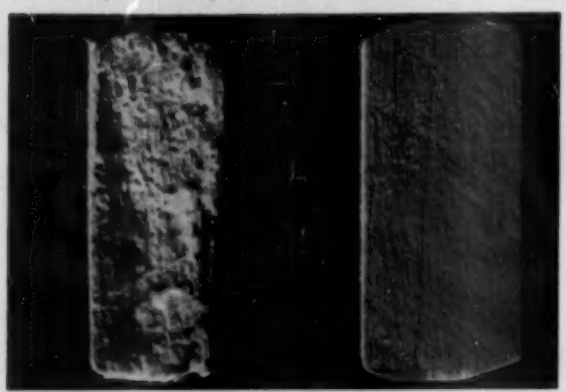

Figure 4. After undergoing an accelerated exposure to a rot fungus, the bare wood block on the left has been reduced substantially in size and weight compared with an untested block.

Photo courtesy of Firmaline Products, Inc.

Figure 2. Test specimens of wood encased in reinforced plastics were prepared by cutting glass mat (lower left), saturating with polyester resin (cup), wrapping this around a balsa block and inserting in the steel dies shown.

TABLE I

Comparative Weight-Time Relation of Three Test Materials Under Water Immersion Expressed as Percent of Equilibrium Weight

Condition	Bare Balsa[A]	Glass Mat/Polyester Laminate	Balsa[A] Encased in Glass Mat/Polyester
Equilibrium (After 14 days at 22°C and 85% relative humidity)	100	100	100
Immersion under vacuum—1 hour	164	103	101
72 additional hours immersion—no vacuum	304	105	114
24 hr. more immersion[B]	305	105	116
24 hr. more immersion[B]	311	105	117
Oven-dried to 0% moisture content	89	100	99+

[A] Flat-grain
[B] The final hour of the 24-hour period was under vacuum.

All blocks were sterilized by autoclaving prior to their introduction into the decay chambers. The proper blocks were then placed on sterile glass rods which had been inserted in the decay chamber to support the specimens clear of the agar. The chambers were capped, placed in an incubator and held at 23°C and 80-90% relative humidity. Humidity conditions within the chambers were considered to be 100%.

One series of blocks remained in the decay chambers for 100 days, another for 185 days, and a third for 191 days. The 100-day series was removed from the incubator after two weeks and kept at room temperature for the remainder of the test.

In addition to specimens exposed to the decay fungi, bare and encased blocks were exposed to identical experimental conditions, with the exception that they completed the test cycle within sterile, uninoculated decay chambers. These uninoculated specimens were used to assay the effect of the test cycle upon the specimens (Fig. 3).

Size measurements were made with a caliper of oven-dry specimens at the beginning and the end of the test. Measurements of bare blocks and those encased in sandwich laminates were considered to be of an accuracy of ±0.02 cm. Resin-coated blocks had a measurement tolerance of ±0.03 cm. Five measurements were made of the three dimensions of one block in each class, and the range of the measurements in each class was used to establish the degree of experimental error which might be attributed to this source.

Decayed wood typically shrinks more during drying than sound wood. Dimension changes in wood, whether due to moisture content, fungus attack, or any other reason, are always smaller along the grain than in the other two directions. Thus, in this experiment, significant shrinkage is calculated as an average of the two dimensions which are normal to the grain.

Testing Results

Weight losses of individual bare balsa blocks varied from 2.0-60%; averaged weight losses for all replicates

Figure 5. Comparison of three typical blocks at the conclusion of 100 days exposure to *Poria monticola*. Bare block, left, is overgrown by fungus. Block encased in reinforced plastics, center, is virtually free of fungus. Resin-coated block, right, shows one end with some attached fungal growth.

are given in Table II. Oven-dried bare blocks which had been subjected to the decay test exhibited severe shrinkage and frequently fell apart upon drying (Fig. 4). The color of the decayed blocks varied from light to dark brown following the tests, as opposed to a white coloration prior to the tests. Examination under low power magnification revealed that wood pores were enlarged and darkened around the edges.

Reinforced plastics-encased specimens, both drilled and undrilled, and the polyester resin-encased specimens showed weight losses which ranged from 0.5-1.1%. Other studies have indicated that sandwich laminates have a tendency to lose small amounts of weight in service (Ref. 1). When similar specimens were run through the test cycle, but not exposed to decay fungi, comparable weight losses of from 0.6-1.0% occurred (Table III). The evidence indicates that this small, uni-

TABLE II

Changes in oven-dry weight and dimension of various plastics-encased balsa blocks and bare balsa blocks following exposure to wood decay fungi.

Treatment and grain direction	# of Replicates	Average ODW prior to exposure (gms)[A]	Average ODW after exposure (gms)[A]	Average weight loss as % of original ODW	Ave. % change in dimensions normal to grain
Bare wood, flat, P[B]	10	1.944	1.278	34.3	—6.8
Bare wood, flat, L	10	1.960	1.850	5.6	—0.3
Bare wood, end, P	5	2.634	1.983	24.7	—4.2
Bare wood, end, L	5	2.589	2.317	10.5	—2.3
RP[C] encased, flat, P	5	11.493	11.425	0.6	E
RP encased, flat, L	5	10.846	10.777	0.6	E
RP encased, end, P	5	13.412	13.346	0.5	E
RP encased, end, L	5	12.993	12.923	0.5	E
RP encased, drilled,[D] flat, P	5	9.767	9.691	0.8	0.0
RP encased, drilled, flat, L	5	9.834	9.767	0.7	0.0
RP encased, drilled, end, P	5	10.728	10.662	0.6	0.0
RP encased, drilled, end, L	5	11.000	10.932	0.6	0.0
Polyester resin coated, flat, P	5	7.417	7.338	1.1	0.0
Polyester resin coated, flat, L	5	7.803	7.730	0.9	0.0
Polyester resin coated, end, P	5	9.648	9.567	0.8	0.0
Polyester resin coated, end, L	5	9.782	9.709	0.7	0.0

[A] Average of all replicates. [B] P = *Poria monticola;* L = *Lenzites saepiaria.* [C] RP = reinforced plastics. [D] Reinforced plastics encased, then drilled to expose wood, then patched with resin. ODW = oven dry weight. [E] = no measurements taken.

form weight loss cannot be ascribed to the action of the decay fungi, but is related to the exposure conditions imposed during the test cycle. It is reasonable to attribute this weight loss to the volatilization of styrene from the polyester resin. It was observed that the moisture changes induced throughout these tests did not affect the integrity of the resin or the resin and glass coatings.

To further test the possibility that some of the fungus threads had penetrated through the sandwich laminate into the wood, one reinforced plastics-encased block was split open following the fungus exposure test, but prior to oven-drying. Microscopic examination of fragments of wood tissue failed to reveal the presence of any fungus. A series of cultures were made from bits of the wood core on petri plates which contained sterile malt agar. If wood infected by fungi is so treated, typically the fungus will grow out into the agar. No such growth occurred in this case. This is considered as further proof that when wood encased in sandwich laminates was exposed to conditions favorable for decay, the protective action of the laminate prevented fungal penetration.

When encased blocks which had been subjected to the tests were cut open for examination, there was no shrinkage or separation of core from skins, discoloration or any other evidence of decay (Fig. 6). If the wood had been decayed, this wood-to-coating bond probably would have broken under the shrinkage stresses imposed upon drying at the conclusion of the test. This is considered as important evidence that the strength qualities of the wood were not affected by the rigorous conditions imposed by these experiments. Blocks at test conclusion are shown in Fig. 5.

Bare balsa blocks (with the exception of flat-grain blocks exposed to *L. saepiaria*) were significantly reduced in size following exposure to decay fungi. The shrinkage in specimens exposed to *P. monticola* was greater than in those exposed to *L. saepiaria*. This fact, when correlated with the smaller weight loss in bare blocks exposed to *L. saepiaria* and the slower growth rate of this fungus in culture, indicated that *L. saepiaria* rotted wood at a much slower rate than did *P. monticola* under the conditions of this test.

Measurements of the resin-encased and the reinforced plastics-encased blocks revealed that no changes in dimension had taken place during the exposure test. Slight variations in these measurements were of a size which fell within the limits of the defined experimental error ascribed to inconsistencies in measurement. The

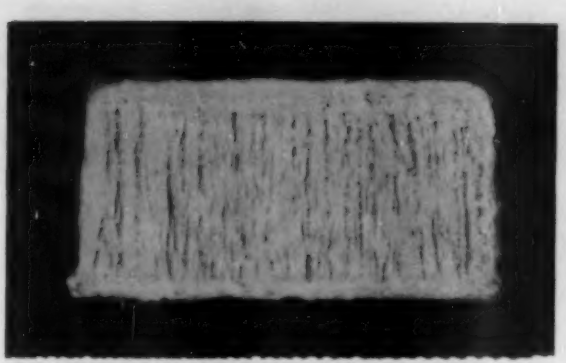

Figure 6. A cross-section of a block of end-grain balsa encased in reinforced plastics. This block was exposed to a rot fungus and has been cut open for examination. No evidence of decay was found.

shrinkage figures, to which a correction factor based on the experimental error has been applied, are computed as the average percent change in the two dimensions normal to the grain (Table II, Column 6).

Subjection of Rot Fungi to Chemical Contact Tests

It was the purpose of these tests to assay the effects of various polyester and epoxy resin chemicals and chemical combinations on cultures of wood decay fungi. It was noted prior to making these tests that several of the chemicals commonly used in resin formulations are closely allied to compounds of commercial significance as fungicides (Ref. 8).

A total of twenty-three chemicals or chemical combinations were tested against two wood decay fungi, *L. saepiaria* and *P. monticola* (Table IV). Two cultures received no chemical treatment, giving a total of 48 units in the experiment. Culture plates (Fig. 7) which contained a nutrient substrate were inoculated with small, approximately equisized bits of the fungi, and then 10 ml. of a chemical was added to a previously designated plate. Thus each of the 23 chemicals were tested once against each of the two fungi.

The 10 ml. of chemical was calculated to cover the nutrient substrate to a depth of 0.16 cm. The type of coverage varied, depending on the nature of the chemical. Very viscous materials, such as Versamid 125, did not flow freely enough to cover the entire culture plate. Benzoyl peroxide, the only powdered material used in this test, was dusted around the inoculum and a few

TABLE III

Changes in oven-dry weight and dimension of various plastics-encased balsa blocks and bare balsa blocks following exposure to the test cycle, but not to decay fungi.

Treatment and grain direction	# of Replicates	ODW[A] prior to exposure (gms.)	ODW after exposure (gms.)	Weight loss as % of original ODW	Ave. % change in dimension normal to grain
Bare wood, end	1	2.500	2.500	0.0	0.0
RP[A] encased, flat	1	12.580	12.500	0.6	C
RP encased, end	1	12.240	12.140	0.8	C
RP encased, drilled[B] end	1	10.950	10.880	0.6	0.0
Polyester resin coated, flat	1	7.595	7.520	1.0	0.0
Polyester resin coated, end	1	9.965	9.880	0.9	0.0

[A] RP = reinforced plastics: ODW = oven dry weight.
[B] Reinforced plastics-encased, then drilled to expose wood, then resealed with resin.
[C] = no measurements taken.

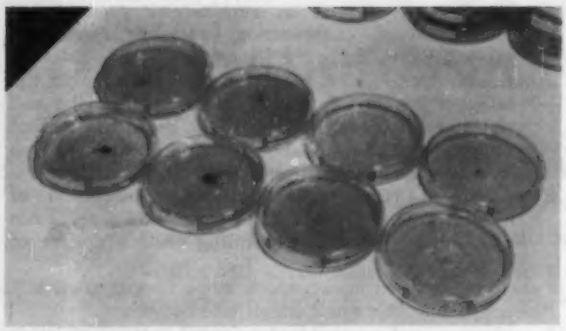

Figure 7. Culture plates containing wood decay fungi on agar, exposed to various epoxy and polyester resin chemicals. The dark spot at the center of each plate is the fungal inoculum.

grains allowed to make contact with the fungus. In all cases the inoculum remained in contact with the substrate, and in a few instances the chemical covered the inoculum. Cultures were examined at intervals for 6 weeks, at which time the experiment was concluded.

Three weeks following the inception of the experiment the plate inoculated with *P. monticola* was fully covered by the fungus, whereas the plate inoculated with the slower-growing *L. saepiaria* was 1/3 covered. In contrast, none of the cultures which had been treated with chemicals showed any growth. In two cases the fungal inoculum appeared to have been hydrolyzed by the chemicals. These instances occurred when (100p) Epon 815, (8p) Shell diethylenetriamine and Shell diethylenetriamine alone were tested against *P. monticola*. The same chemicals tested against *L. saepiaria* caused blackening of the inoculum but did not hydrolyze the fungus tissue.

Discussion

The conclusion drawn from the results of the testing program undertaken by the authors and study of the work of other agencies is that a complete covering of reinforced plastic prevents decay in kiln dried wood under any service moisture condition. This is apparently due to initial sterilization of the surface by resin contact and subsequent exclusion of decay fungi by the covering.

It should be emphasized that, since the data given in this paper concerns lumber or plywood which has been kiln dried by the manufacturer, no conclusions can be drawn on wood which is green or air dried. Green or air dried lumber may contain living fungi within the wood which would not be contacted by resin on the surface at the time of lamination.

It is not possible, of course, to test for all possible conditions of moisture; however, rot fungi can ordinarily develop in wood if the moisture content is above the fiber saturation point of the wood. Boyce (Ref. 9) states "although wood can decay at a moisture content as low as 15% based on oven-dry weight, wood must usually reach fiber saturation point, which varies from 25 to 32%, before decay becomes severe."

There is also an upper inhibition point for fungus development which depends on the specific gravity of the wood. In lightweight species this is over 200% based on the oven dry weight of the wood. Considering weight increases in the encased blocks in these test as being entirely moisture uptake by the wood, the balsa core varied, in the extremes, from 14% to 201% moisture content at the conclusion of the experiments. The uniformity of test results over this wide range lends strong support to the statement "under any moisture condition," meaning any moisture condition subsequent to fabrication of the sandwich.

There are several ways in which resin can sterilize the wood surface. The surface will almost invariably have fungal spores resting on it—spores dormant and ungerminated unless favorable environmental conditions occur—but still present. The test in which decay fungi were subjected to direct contact with some common resin components demonstrated chemical toxicity. The temperature at which the resin is applied is also sufficient, in many cases, to kill spores.

Although direct contact of resin ingredients was tested, there is also the possibility of toxicity from fumes, which was not tested.

The purpose of the test was to assay the effects of these materials on wood decay fungi *in vitro* at concentrations which contact the wood surface during the lamination process. Some of the components of these resins may have value as commercial fungicides, but the concentrations used here were too high for these tests to be considered of value as an assay for end-use of these materials as commercial fungicides.

TABLE IV

Chemicals which were tested against decay fungi

1. Laminac 4128.
2. Stypol 12.
3. Union Carbide Styrene monomer.
4. (1p) Nuodex 6% Cobalt naphthenate, (9p) U.C. styrene monomer.
5. Lupersol DDM (60% methyl ethyl ketone peroxide, 40% dimethyl phthalate).
6. Cadet benzoyl peroxide.
7. (85p) Laminac 4128, (15p) Stypol 12, (10p) U.C. styrene monomer.
8. (85p) Laminac 4128, (15p) Stypol 12, (0.25p) Nuodex 6% Cobalt naphthenate, (2.25p) U.C. styrene monomer.
9. (85p) Laminac 4128, (15p) Stypol 12, (1p) Lupersol DDM.
10. (85p) Laminac 4128, (15p) Stypol 12, (0.25p) Nuodex 6% Cobalt naphthenate, (12.25p) U.C. styrene monomer, (1p) Lupersol DDM.
11. (85p) Laminac 4128, (15p) Stypol 12, (1p) Cadet benzoyl peroxide, (0.25p) Nuodex 6% Cobalt naphthenate, (12.25p) U.C. styrene monomer, (1p) Lupersol DDM.
12. (85p) Laminac 4128, (15p) Stypol 12, (10p) U.C. styrene monomer, (1p), Cadet benzoyl peroxide.
13. (85p) Laminac 4128, (15p) Stypol 12, (0.25p) Nuodex 6% Cobalt naphthenate, (12.25p) U.C. styrene monomer.
14. (85p) Laminac 4128, (15p) Stypol 12, (10p) U.C. styrene monomer, (1p) Lupersol DDM.
15. (85p) Laminac 4128, (15p) Stypol 12, (0.25p) Nuodex 6% Cobalt naphthenate, (2.25p) U.C. styrene monomer, (1p) Lupersol DDM.
16. Epon 815.
17. Epon 820.
18. (100p) Epon 820, (100p) Versamid 125.
19. (100p) Epon 815, (8p) Shell diethylenetriamine.
20. (100p) Epon 815, (20p) Epon Curing Agent T.
21. Versamid 125.
22. Epon Curing Agent T.
23. Shell diethylenetriamine.

Summary

The subjection of bare balsa wood blocks to wood-destroying fungi provided data on the ravages of decay which were compared with that obtained when reinforced plastics-encased and resin-encased wood were exposed to the same accelerated decay conditions. Following the test, the bare specimens had decreased in oven dry weight, changed in color, developed large cracks on drying, and shrunk more on drying than sound wood. It was possible to culture the wood decay fungi used from the interior portions of these blocks. None of the three types of encased specimens used in these tests showed any of these evidences of decay when examined after the exposure period.

Minor weight losses in encased blocks occurred at the same rate whether the specimens were exposed to the decay fungi. These weight changes were attributed to the exposure conditions imposed by the test cycle. Moisture levels maintained within the wood were sufficient to support decay had fungi penetrated the resin or resin-glass coatings, but such penetration apparently did not occur.

Bare wood blocks were completely enveloped by fungal growth at the completion of the test. In contrast, fungi did not envelop the encased blocks, and only rarely small wefts of fungal tissue adhered to these blocks (Fig. 5). It is probable that neither the glass-polyester laminate nor the polyester encasement afford a hospitable substrate for the growth of the wood-destroying fungi used in these tests.

The results of this investigation show typical commercial polyesters as being at least fungistats when undiluted. Since the polyester component normally comprises at least 70% of the resin formulation, it can be expected that a polyester formulation will be at least fungistatic and that other additives, such as an organic peroxide, may raise its level of toxicity. The same reasoning holds for epoxy resins where the addition of an aliphatic amine, such as diethylenetriamine as a curing agent, may add to its fungi-toxicity.

In view of the facts presented and the evidence gathered within the experimental design of the tests reported in this paper, the authors conclude that a complete covering of reinforced plastics prevents decay in kiln dried wood under any service moisture condition.

Glossary

Poria monticola — A fungus of the plant family Polyporaceae. It is also called *Poria microspora*. It causes rot in both living trees and wood in service. Although it principally attacks coniferous wood, the US Forest Products Laboratory has established it as a decayer of balsa, an angiospermous wood, as well (Ref. 1). Boyce (Ref. 9) and Cowling (Ref. 13) list it as an important fungus causing decay in wooden boats.

Lenzites saepiaria — A fungus of the plant family Polyporaceae. It has world-wide distribution and attacks the wood of both coniferous and angiospermous species. It is also listed by Boyce (Ref. 9) and Cowling (Ref. 13) as an important fungus causing decay in wooden boats.

Culture — Controlled fungus growth on a nutrient media such as malt agar.

End-grain block — A piece of wood whose grain is perpendicular to the face of the piece. End-grain cores are primarily employed in aircraft and missile sandwich construction.

Flat-grain block — A piece of wood whose grain is parallel to the face of the piece. Flat grain cores are primarily employed in commercial products of sandwich-type construction, such as reinforced plastics boats.

Fiber saturation — A condition in wood wherein the cell cavities are devoid of moisture, but the cell walls are fully saturated. If the moisture content of a piece of wood is above this point, there is free water in the cell cavities.

Fungitoxic — Causing alteration or inhibition of normal fungus growth. The effect may range from very mild to lethal, depending on the degree of toxicity.

Fungistat — An agent which stops fungus growth.

Fungicide — An agent which kills fungi.

Inoculum — A segment of a fungal culture which is removed and placed on another nutrient media to start new growth.

Mycelium — A mass of interwoven fungus threads.

Spore — The reproductive product of a fungus. Viable spores are capable of generating new fungus growth in the same sense that seeds propagate higher plant life. Spores are not visible to the unaided eye.

Thread — The minute branching filament of cells which is the basic form of fungus vegetation. Threads are also known as hyphae.

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Polymerization with Radiation

A critical evaluation of the application of ionizing radiation in polymerization, cross-linking and graft copolymerization with respect to economics; advantages and disadvantages as compared with conventional chemical methods; and feasibility in terms of available sources, radiation damage, shielding and uniformity of radiation dose.

Part I—General Considerations

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This is the first of two parts. Part II, Technical Considerations by Robert McFedries, will be published in the October issue of the SPE Journal.—editor

IN THEORY, at least, production of high polymers by ionizing radiation is promising in that it offers many advantages over the conventional chemical methods. We must, however, consider the practical aspects of radiation before we can accept it as a suitable solution to production problems.

Possible applications of ionizing radiation include such topics as: the rapid curing of styrene-polyester-glass fiber systems; improved resistance to heat and stress corrosion of polyethylene through radiation cross-linking; the development of entirely new types of copolymers for use as molding powders, films and fibers by graft copolymerization; new techniques for increasing the printability of polyethylene films. These potential applications have been pointed out on several occasions by Ballantine (Ref. 1) (Ref. 2), Charlesby (Ref. 3), and others (Ref. 4) (Ref. 5).

Atomic radiation has already made important contributions to plastics science in areas of polymerization, cross-linking or vulcanization and graft copolymerization. These contributions have been both the direct ones, which any new tool always affords, and indirect ones through stimulation of work in the more conventional fields of organic and physical chemistry. The impact of ionizing radiation on organic matter generates free radicals which then promote such reactions as polymerization, cross-linking and graft copolymerization. However, free radicals have long been available to the polymer chemists via peroxides, azo compounds, ultraviolet light and the like.

It is inevitable that an intense and interesting contest will ensue between the radiation chemist and the organic or physical chemists. The outcome of this contest will determine the future role of radiation in plastics technology. Many factors—some subtle, others still unknown—are involved; but the main factors deciding the future role of atomic radiation in plastics technology revolve around: (1) economics of radiation; (2) advantages and disadvantages of radiation compared with conventional chemical methods; and (3) feasibility, in terms of available sources, radiation damage, shielding, uniformity of radiation dose.

Some preliminary assessment of the probable role of radiation chemistry in plastics techology, both present and future, can only come from a critical evaluation of the above factors. Such an approach appears necessary now because more is known about the interaction of ionizing radiation with organic matter. Moreover, the probable cost and supply of such radiation is becoming more accurately known. And finally, competitive chemical methods which have been stimulated by the feats of radiation chemistry are beginning to show up.

Polymerization

Some ten years of study on the interaction of ionizing radiation with organic matter has now demonstrated rather thoroughly that free radical reactions are involved. Hence, one would expect such ionizing radiation to accomplish the familiar act of polymerization which has been performed up until now with conventional free radical catalysis. The advantage of ionizing radiation is the production of free radicals essentially independently of temperature. The disadvantage is that such radiation must be shielded because of its highly penetrating nature. It is, moreover, relatively non-selective in its attack on organic materials.

For example, in the polymerization of vinyl chloride a peroxide catalyst is usually employed. We can picture hydrogen peroxide as such a catalyst. In that case, the sequence of steps in polymerization is indicated below:

$$H_2O_2 + \text{Heat} \rightarrow HO\text{-}$$
$$HO\text{-} + CH_2{=}CHCl \rightarrow (CH_2CHCl)\cdot$$

The advantages of this system are simplicity and considerable industrial experience.

We can list some possible disadvantages of this old conventional procedure, although they cannot be considered too serious in view of the large-scale production of PVC.

1. In the first place, the hydrogen peroxide is a foreign material added to a pure monomer.

2. Heat is required to decompose the peroxide into the two free radicals, HO-. In general, each peroxide has a characteristic temperature range in which it decomposes, and this fixes the temperature of polymeriza-

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TABLE I

Comparison of the Radiation Polymerization of Styrene and Vinyl Chloride

Monomer	Cost of Radiation for 100% Conv.[a] 100 R/Min.	Cost of Radiation for 100% Conv.[a] 100,000 R/Min.	Advantages of Radiation	Disadvantages of Radiation
Styrene	8.6¢/lb.	$8.60/lb.	Operate from −30°C up	Cost
	(1430 hr.)[b]	(143 hr.)[b]	Possibly better properties[c]	Shielding
Vinyl Chloride	0.2¢/lb.	5.2¢/lb.	Operate from −160°C up	Shielding
				Possible degradation
	(33 hr.)[b]	(0.9 hr.)[b]	Polymer free of catalyst residues	Branching

[a] Assuming 1¢/lb. megarep-pound, and using polymerization rate data of Ref. 4a. 100 R/Min. is a dose rate of 100 Roentgens of gamma radiation per minute.

[b] Time required for complete conversion of monomer to polymer.

[c] Callinan (Ref. 6) has found a 14-20°C higher heat distortion, and lower water absorption for radiation cured polystyrene.

tion. This temperature, which is dictated by the peroxide used, may not be the most desirable temperature because of some other complication. Actually, there is available a wide range of peroxides, decomposing in various temperature ranges above room temperature, so that this is not normally a serious limitation.

3. The peroxide may enter into side reactions, such as chain transfer, which are undesirable.

4. The level of peroxide is changing throughout the course of the polymerization and this may give rise to a drift in molecular weight and rate of polymerization. This can be overcome by various schemes but is still a nuisance.

5. Residual end groups from the peroxide fragments may cause problems with thermal stability.

Now we might consider what would happen if radiation is used to induce polymerization in vinyl chloride. The sequence of steps is indicated below:

$$\text{Radiation} + CH_2{=}CHCl \rightarrow R\text{-}^{*}$$
$$R\text{-} + CH_2{=}CHCl \rightarrow (CH_2CHCl)_n$$

*Free radical of unknown nature.

The possible advantages in using radiation are:

1. No foreign chemical substance is added.

2. The rate of production of such radicals is essentially independent of temperature at any temperature above the freezing point of the monomer and hence the polymerization temperature can be chosen to maximize some given property. Some monomers can actually be polymerized in the solid state.

The disadvantages of radiation are:

1. The highly penetrating nature of the radiation means that the reaction must be carried out in a well-shielded area which in general will require a whole new set of research and production techniques.

2. The use of too much radiation may start degradation reactions leading to color in the finished polymer.

3. Once the conversion of monomer to polymer gets beyond a certain point, the radiation may induce branching reactions. This results because more of the radiation is absorbed by the polymer as the monomer supply is depleted. Free radicals formed on the polymer (see later section on Graft Copolymerization) will induce a side branch of PVC to grow on already existing polymer. There may even be an acceleration of polymerization rate as polymerization proceeds, because polymers are usually more susceptible to radiation than are their monomers.

Finally, there is the question about the economics of radiation. We might take for comparison two extreme examples, the polymerization of styrene and vinyl chloride using gamma radiation as shown in Table I. Styrene monomer exhibits a very low rate of polymerization because the benzene ring is resistant to radiation. Vinyl chloride has a high rate of polymerization. In the case of styrene and assuming that radiation costs about 1¢/megarep pound, we can see that it would be quite uneconomical and time consuming to polymerize styrene by radiation. Moreover, styrene polymerizes very well with heat alone and no catalyst is normally required. Hence, there is no incentive to employ radiation catalysts with styrene. Vinyl chloride polymerizes at such a fast rate that it is probably economical to use ionizing radiation even at the present time as a subsitute for peroxide catalysts. Assuming that costs of conventional catalysts and radiation are roughly equivalent, it is still debatable whether any advantage obtained by the elimination of a conventional catalyst is sufficient to offset the trouble of using shielding and the delicate balance between employing just enough radiation to cause polymerization but not enough to start degradation. It may be sometime before questions of this type will be solved by experimental facts and detailed engineering studies.

A brief comment is in order about the higher costs of radiation catalysis per pound of polymer at the higher dose rates in Table I. This arises because polymerization is a chain reaction whose rate increases as the square root or less of the radiation intensity.

We conclude that even at present radiation costs it is economical to polymerize vinyl chloride with radia-

tion, if tests should prove that the resulting polymer is superior to conventional PVC. It also appears feasible to polymerize vinyl chloride since cobalt 60 sources of adequate strength are available, and shielding problems are well understood. The detailed engineering problems of modifying a polymerization vessel—say a Pfaudler kettle—to accommodate the cobalt 60 source still remain to be worked out. It is not now economical to polymerize styrene by radiation, but might be in the future when radiation costs are about 0.1% of present values. It is possible that the use of radiation accelerators would reduce cost, but this involves adding a foreign material to the monomer. Fig. 1 of Ref. 3a indicates that the addition of 10% carbon tetrachloride to styrene monomer gives a four-fold increase in polymerization rate. The polymer thus formed will contain bound chlorine which might cause mold corrosion or poor electrical properties.

A strong case for radiation can probably be made in connection with the copolymerization of styrene monomer with unsaturated polyesters. The normal styrene-polyester system contains a peroxide catalyst to shorten the final cure time. However, the presence of this catalyst tends to cause premature gelation and hence to reduce pot life of the styrene-polyester system. Lawton (Ref. 7) and Charlesby (Ref. 8) have demonstrated that such styrene-polyester systems can be cured with high velocity electrons while Callinan (Ref. 6) and Ballantine (Ref. 9) have used gamma rays for this same purpose. Henson and co-workers (Ref. 10) have demonstrated that the use of Van de Graaff electron beams can cure styrene-polyester systems on glass fiber in times as short as 10 seconds, as compared with 3 to 15 minutes for conventional peroxide cures. Moreover, these workers have found that such styrene-polyester systems can be loaded with inhibitor to prolong pot life without interfering with subsequent radiation curing. It would seem that radiation curing of styrene-polyester systems offers sufficient advantages in longer pot life and reduced curing schedules to overcome the trouble and costs of using ionizing radiation. The continuous curing of flat sheets of styrene-polyester-glass fiber is probably feasible at the present time using electron accelerators. The width of electron beam available today is a limiting factor for curing wide sheets, but two or more accelerators can be employed to get two or more scanned electron beams operating side by side on the same sheet. The curing of complex, irregular shapes made from styrene-polyester-glass fiber, such as gunk moldings, may not be feasible at present. Such a cure would appear to require rotating the part in an electron beam, or using a powerful cobalt 60 source arranged to produce a uniform radiation field.

An important new aspect of polymerization is the surface type catalyst which produces stereospecific or crystalline polymers from such monomers as propylene. It seems doubtful that radiation could compete in the near future, partly because these catalysts seem to involve an ionic rather than a free radical mechanism and also because they appear to require a solid surface.

Cross-linking

The basic reaction in the cross-linking or vulcanizing polyethylene, GR-S rubber, silicone rubber and other polymeric materials appears to be expulsion of hydrogen atoms from adjacent polymer chains, with the free radicals thus produced coupling to form a cross-link.

At the same time it is well known that rubber can be cross-linked with sulfur while polyethylene can be cross-linked with peroxides and other substances, or by ultraviolet light plus the use of special sensitizers as shown by the recent work of Oster and co-workers (Ref. 11). What then are the relative advantages of chemical and radiation cross-link? The conventional chemical methods with sulfur or peroxides require the addition of foreign agents to the polymer with the attendant problems of thorough mixing. They also require the elevated temperatures and prolonged curing times which are characteristic of chemical reactions. The ultraviolet light method of Oster is limited in thickness of penetration because of the absorption of ultraviolet light in many organic materials, or the scattering of light in crystalline polymers.

Radiation does not require a foreign material to accomplish the cross-linking, although certain additives such as antioxidants are desirable to prevent side reactions. Secondly, the cross-linking can be carried out over an extremely wide range of temperatures, and preferably at low temperatures which avoid distortion of shaped articles. The rate of cross-linking will depend

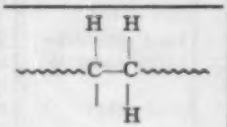
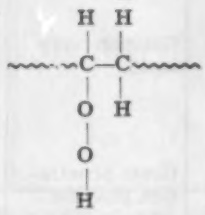
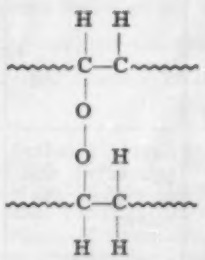
TABLE II

Comparison of Various Methods of Cross-Linking Polymers

Method	Advantages	Disadvantages
Ionizing Radiation	No vulcanizing agent needed	Cost & complexity of radiation facilities
	Low temperatures possible	Buried free radicals which can cause subsequent oxidation
	Reaction very rapid	Peroxy cross-links which decompose at elevated temperatures
	Great penetration possible	Some degradation of polymer chains
		Probable need for very effective antioxidants & anti-staining agents
Chemical	Simple, standard equipment and operations involved	Foreign agents must be added
		High temperatures and/or long times required
		Heat transfer problems
		Foreign agents should be added
Ultraviolet Light	Simple, inexpensive equipment required	Dept of penetration limited by absorption and/or scattering of light

TABLE III

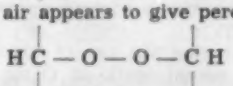
Types of Active Sites on Polyethylene Backbone Which Can Induce Graft Copolymerization of Vinyl Monomer

Active Site	Structure[a]	How to Produce Active Sites: By Atomic Radiation	How to Produce Active Sites: By Conventional Chemistry	Conditions Necessary for Grafting
Free Radical		Radiation in absence of O_2 or in presence of a monomer	Peroxide catalysts	Add monomer at R.T. Add monomer + radiation Add monomer + peroxide + heat
Hydroperoxide		Radiation in presence of some O_2	Heat oxidation; U.V. light + O_2	Add monomer + sufficient heat to decompose peroxide
Diperoxide		Radiation at slow rate in presence of O_2	Heat oxidation; U.V. light + O_2	Add monomer + sufficient heat to decompose peroxide

[a] One monomer unit in a long chain of polyethylene is indicated

on temperature in crystalline materials such as polyethylene, although this is a second-order effect which is rather minor in magnitude compared to the temperature coefficient of most chemical reactions (Ref. 12). Thirdly, ionizing materials eliminate the heat transfer problem involved in curing thick sections. Fourth, radiation curing is practically instantaneous except in certain highly crystalline polymers. These various points are summarized in Table II along with some possible disadvantages of radiation.

Chapiro (Ref. 13) has shown that cross-linking of polyethylene in air appears to give peroxy cross-links:



These act like normal carbon cross-links at room temperature, but break down at elevated temperatures. This effect is very pronounced with a low intensity source, such as cobalt 60, where the long irradiation times required allow sufficient time for oxygen diffusion. This implies the desirability of cross-linking in the absence of air if low radiation dose rates are employed. The high dose rates (and correspondingly short cure times) available from modern electron accelerators appear to minimize this oxygen problem.

It still appears, judging from a patent recently issued to Sequoia (Ref. 14) that an effective antioxidant, as well as a second additive which may confer non-straining characteristics, are desirable additives even with electron beam cross-linking of polyethylene.

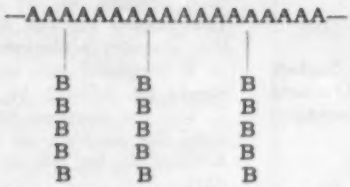
Lanza (Ref. 15) has indicated that a dosage of 8 to 16 megareps costing a maximum of 8 to 16¢/pound will correct the temperature and stress corrosion problems of polyethylene. This radiation dose allows polyethylene to compete, for most practical purposes, with much more expensive polymers.

It thus appears that a strong case can be made for radiation cross-linking of polyethylene, with various restrictions applying to other polymers depending on the specific polymer system involved. Polystyrene, for example, is extremely resistant to cross-linking, but recent studies (Ref. 16) indicate that sensitizers like paradibromobenzene greatly reduce the radiation dose needed for cross-linking. Still other polymers (see Table IV) degrade so badly with atomic radiation that radiation cross-linking is ruled out.

Graft Copolymerization

A new and rapidly growing phase of polymer science, graft copolymerization, has been the subject of several extensive literature reviews (Refs. 17, 18, 19, 20). A number of methods have been devised to effect graft copolymerization, of which radiation is the newest.

Graft copolymerization is the process of causing monomer B (the grafting monomer) to grow out from, and be firmly attached to, an existing polymer A (the backbone polymer). In the simplest case, abstraction of a hydrogen atom from a polyethylene chain leaves a carbon free radical on the polyethylene chain. If a monomer such as styrene is brought into contact with this free radical, the monomer will polymerize to give a brochure or grafted copolymer with the following structure:



Such a graft copolymer can combine some of the best physical properties of the two pure polymer species. In the example above, the strength and hardness of polystyrene would be superimposed on the toughness and crystallinity of polyethylene. Such graft copolymers represent a new class of polymeric materials which should, in general, have properties superior to conventional copolymers of the type illustrated below:

—AABABBBAABA—

Graft copolymerization can also be induced by hydroperoxide or diperoxide groups formed on polymer chains, as indicated in Table III. This table emphasizes that while all three types of active sites can be produced by ionizing radiation, they can also be formed by conventional chemical means.

Radiation grafting itself can be accomplished by a variety of methods which are becoming evident from the recent literature and patent references. There are already at least six variations of radiation grafting, some of which differ only in minor details:

1. The Mutual Radiation Method of Magat, Chapiro and Sebban in which monomer is dispersed in polymer and the mixture subjected to radiation (Refs. 4c, 21, 22).

2. The Pre-Radiation Method by the same workers in which a polymer is first irradiated in the presence of air, which presumably gives rise to peroxide groups, and then contacting the irradiated polymer with monomer plus heat (Refs. 4c, 21, 23).

TABLE IV

Sensitivity of Polymers to High Energy Radiation*

Polymer	Total Dose To Produce 25% Damage (Megarads)
Polystyrene	>4000
Polyester	3900
Phenolic Asbestos Filled	890
Polyethylene	93
Vinyl-Vinylidene Chloride	45
Methyl Methacrylate	11
Polytetrafluoro-ethylene	0.037

*References 36, 37

3. Pre-radiation in the absence of air, followed by contact with monomer, which appears to have been used by Wall and Brown (Ref. 24). Bevington (Ref. 25) and LeClair (Ref. 26).

4. The Brookhaven Method (Ref. 27) in which a sample of polymer is placed in monomer and the system irradiated. The center of the sample presumably undergoes pre-radiation in the absence of air, as in Method 3 above, while the surface experiences mutual radiation as in Method 1 above. The Brookhaven group has also worked with Method 1 as well as with the grafting of two polymers which have been thoroughly mixed together.

5. Pre-radiation of the surface of films and fibers in the presence of hydrogen peroxide or other free radical generating substances, followed by contact with monomer, as taught by Gaylord (Ref. 28).

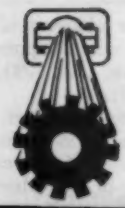
6. The surface grafting of shaped objects such as films and fibers, whereby the object is dipped in a monomer or an organic liquid, excess liquid is removed, and the treated sample is exposed to a high radiation dose. The high dosage and small weight of added material implies quite short graft chains, which probably explains the lack of differentiation between monomeric and saturated organic chemicals as grafting agents. The films and fibers so treated have improved antistatic and dyeing characteristics. Three Belgian patents to Du Pont are involved (Ref. 29). Several of these patents also imply or cover the Mutual Radiation Method 1 above, but with very high radiation doses.

Not only do these various radiation methods compete with each other, but they must also compete with the chemical methods (Refs. 17, 18, 19), with the ultraviolet light techniques (Refs. 11, 30), and with the mechanical milling method of Angier and Watson (Ref. 31).

Criteria for choosing between radiation and chemical grafting are numerous and complex. Any detailed discussion is beyond the scope of this paper, even if all the facts to make the choice were available. Relative sensitivity of monomer and polymer to radiation, tendency of polymer to degrade by radiation in air, and amount of homopolymer (i.e. pure polymer B) formed by the various methods are among the pertinent factors. Cost and convenience are also important factors. It appears certain now that for some polymer-monomer systems—for example, acrylonitrile grafted onto polyvinyl chloride—radiation would be feasible because of the great sensitivity of PVC to radiation. Grafting of acrylonitrile to polystyrene might well require a chemical method because of the extreme resistance of polystyrene to radiation and the consequent high cost of radiation.

Radiation grafting, probably by the mutual method, will likely prove superior for grafting of vinyl monomers onto radiation sensitive polymers like PVC, cellulose derivatives and methyl methacrylate, whereas chemical methods may be preferred for GR-S rubber and polystyrene. Other polymers of intermediate radiation sensitivity, say polyethylene, could go by ultraviolet light or chemical or radiation methods, depending on economics and simplicity. It may still be permissible to ask for unambiguous proof of the desirability of any graft copolymer, and hence, to question any comparison of competitive methods. We belive that available evidence in the literature suggests a strong future for graft copolymers, and the eventual need to make intelligent choices between chemical and radiation grafting.

End of Part I. Part II will be published in the October issue of the SPE Journal.—editor



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SPEAKING of EXTRUSION

Problems in Predicting Screw Performance

L. D. Barr

Plax Corp.

EVER since the time an ingenious individual discovered that a straight edge helically wrapped along the length of smooth cylinder made an excellent extruder screw, the problem of how to predict what will happen when this device is put to use has existed.

Toward this end, a large amount of effort and research has been expended, notably by raw material suppliers, and has resulted in making the art of extruder prediction a more exact science. In particular, equations describing extruder performance have been developed and refined to the point where they can be used as tools to help in the design of new extruder screws.

The simplest and best known of the extrusion equations are based on the simplified flow theory or, more specifically, the isothermal flow theory in which plastic melt temperature is assumed to be constant. Using this fundamental premise, the various research groups have developed simplified flow equations and a suggested procedure for using them. The procedure involves the important step of selecting the proper viscosity value to use in the equations as well as explaining how to interpret the terms in the equations.

Although all of the procedures presented are based on the same basic theory, the equations differ slightly in form, and in addition, the recommended viscosity values are different. For the person using these equations, the question arises as to which of the procedures gives the best agreement with actual practice.

The purpose of this article is to describe a comparison of the predicted extruder output against actual output as performed during a recent series of extrusion tests. Simplified procedures as presented by three different groups were used for comparison in an effort to gain experience in applying the different available techniques.

The equations were examined under three sets of conditions:

1. As calculated using total pressure and the actual metering section channel depth. This is the suggested first approximation procedure as described in Ref. 1, 2 and 3.
2. A second calculation using the increment in pressure across the metering section and the actual metering section depth.
3. Same as (2), but now using an effective channel depth discussed in Ref. 4 instead of the actual depth.

In all cases, results were compared to actual output obtained.

The test was performed on a 3¼-inch constantly decreasing depth screw having a 12-inch metering section and using virgin polyethylene with a 2.0 melt index. More complete specifications are given in Table I.

The screw was installed in a standard production extruder and operated without water cooling at various speeds and pressures. Barrel temperature settings were held constant, although melt temperature was observed to vary slightly with changes in speed and pressure. In general, melt temperature increased with screw speed and end pressure as much as 20°F for higher pressures.

In computing the equations, no provision was made for temperature changes in the plastic melt. The reason for not doing so was that changes in plastics temperature in a proposed but un-built screw would be difficult to predict, and it was the purpose here to determine the accuracy of the equations without having precise performance data.

It is well recognized, however, that temperature changes can affect screw performance quite markedly. In using the equations, therefore, it is well to keep in mind that the predicted output is only as accurate as the assumptions made in evaluating the equations. In short, make as accurate an estimate of conditions as possible, and then select an operational range, using the equations as a guide to indicate how performance may change.

The first approach used was a straightforward examination of each flow equation to see which items of information were needed, and then "plugging" these items into the equation to obtain the predicted resut. In using each of the equations, an effort was made to stay within the bounds of the simplified procedure that pertained to that equation. In all cases, the leakage flow term was negligible.

Fig. 1 shows the equations used for comparison. Term definitions are given in Table I. The equations are also shown after the constant terms have been evaluated for the first calculation. Eq. C calls for the use of an increment in pressure (ΔP) across the melt zone, but as a first approximation, the author recommends using total end pressure which is the same as equations A and B in which one assumes the metering section develops all pressure acting on the end of the screw. This condition was not found to be

TABLE I

Type of Screw = Constant Pitch, Decreasing Depth, Metering
L/D Ratio = 13.5
Screw Diam. (D) = 3.244″
Metering Zone Flight Depth (h) = 0.125″
Metering Length (L) = 12″
Pitch (S) = 3″
Land Width (e) = 5/16″
Helix Angle ϕ = 17° (Eq. B), 16.4° (Eqs. A and C)
Radial Clearance = 0.003″
μ = Melt Viscosity
N = rpm of Screw
P = Pressure at End of Screw
Dm = (D-h)

true in these tests; and, in fact, under certain conditions, the metering section developed none of the end pressure. This effect is discussed in more detail further on.

In all calculations, the total melt zone was assumed to be equal to the metering length, in accordance with accepted procedure.

The vicosity term in the equations presented a problem,since each of the three equations was accompanied by a graph showing the viscosity value to use in the equation. Unfortunately, each graph gave a different value to use. This is a situation that arises from the difficulty in obtaining a general purpose viscosity value that is valid for all polyethylenes having similar melt index numbers. The question remains, however: which value will provide the best approximation?

This dilemma was solved or, perhaps, bypassed by using the viscosity value recommended for each individual equation. This may not have done justice to all of the research groups, but it seemed to be the best way to proceed with the comparison. This problem would arise for any similar calculation of extruder performance without having precise data at hand.

Viscosity values were found from the graphs at an assumed temperature of 320°F, which was the temperature of the last heating zone and the extrusion die. Actual material temperature ranged slightly higher, but not enough to affect the value of viscosity taken from the graphs by more than about 10%.

Values used in the equations were:

Eq. A: Viscosity= 0.13 lb.-sec/in²

Eq. B: Viscosity= 0.28 lb.-sec/in² at 20 rpm
0.195 lb.-sec/in² at 40 rpm

Eq. C: Viscosity= 0.044 lb.-sec/in²

Recent papers presented at the 14th SPE ANTEC give corrections factors that apply to this type of comparison. These are the shape factor and the channel curvature correction factor (Ref. 5). Both factors were found to be negligible (close to 1.0) for this type of screw which has a shallow metering section.

The calculated curves as computed using total pressure and the above viscosity values are compared to actual output in Fig. 2 for two different speeds. In performing the tests, speeds up to 50 rpm were used and the two speeds shown were chosen as being representative.

After making a first approximation as shown in Fig. 2, the equations were recalculated using the increment in pressure across the metering zone (ΔP). This was done to see if any of the equations would be improved by this technique.

Measuring pressures at both ends of the metering section enabled ΔP to be found.

In performing this step, the pressure increment was found to vary almost linearly with end pressure, but starting from a negative value for zero end pressure and passing through zero to a positive value for higher pressures: A negative value occurs when pressure at the beginning of the metering section is higher than at the output end. Furthermore, a change in screw speed was found to shift the line.

Measured values for ΔP were:

+ 500 psi—20 rpm and 3000 psi end pressure

−1000 psi—20 rpm and zero end pressure

+ 175 psi—40 rpm and 3000 psi end pressure

−1300 psi—40 rpm and zero end pressure

Using these values in the equations instead of total pressure gives the lines shown in Fig. 3. Note that ΔP at zero end pressure was needed to determine the "starting" point for the calculated output lines.

The third variation was to use an effective channel depth (h^*) (Ref. 4) which is a technique used to correct for temperature variations across the depth of the screw channel. It may be thought of as an allowance for the slow moving plastics near the screw that has the effect of making the screw channel more shallow.

To find the effective channel depth the first term in the flow equation is used. By examining the flow equation, it is apparent that when ΔP is equal to zero, all of the output is described by the first term (drag flow) since the second term goes to zero. If output for this condition is known, h^* can be calculated from:

$$h^* = \frac{Output}{\alpha N}$$

N = rpm

α = Constant for first term evaluated without using the channel depth (h)

In this test ΔP did become zero, enabling h^* to be calculated. h^* was

Eq. A

$$Q = \frac{\pi^2 D^2 h \sin\phi \cos\phi N}{2} - \frac{\pi D h^3 \sin^2\phi P}{12 \mu L}$$

$$= 3.52 N - 0.00131 \frac{P}{\mu} \text{ (lb/hr)}$$

Eq. B

$$Q = \frac{\pi D_m h S \cos^2\phi N}{2} - \frac{h^3 S \sin\phi \cos\phi P}{12 \mu L}$$

$$= 2.94 N - 0.00119 \frac{P}{\mu} \text{ (lb/hr)}$$

Eq. C

$$Q = \frac{\pi D (S - e) h \cos^2\phi N}{2} - \frac{h^3 (S - e) \sin\phi \cos\phi \Delta P}{12 \mu L}$$

$$= 2.98 N - 0.00116 \frac{\Delta P}{\mu} \text{ (lb/hr)}$$

Actual

$$Q = 3.0 N - \begin{cases} 0.004 P \text{ at } 10 \text{ rpm} \\ 0.006 P \text{ at } 20 \text{ rpm} \\ 0.008 P \text{ at } 30 \text{ rpm} \\ \text{etc . .} \end{cases}$$

Figure 1. Flow equations.

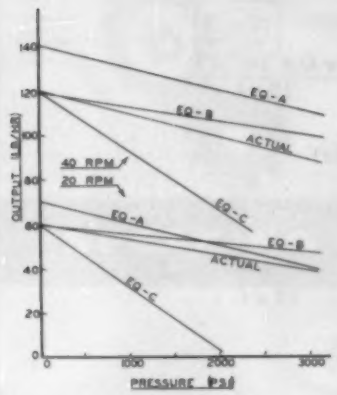

Figure 2. Output vs. pressure.

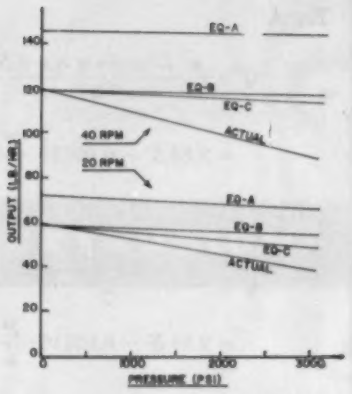

Figure 3. Output vs. pressure using actual ΔP in calculations.

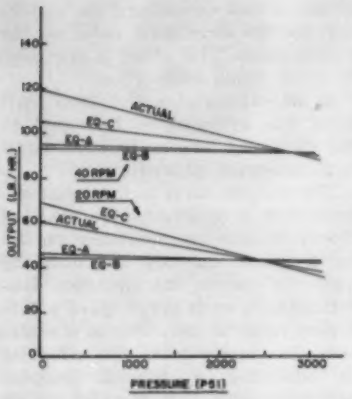

Figure 4. Output vs. pressure using ΔP and h^* in calculations.

then used in the third calculation, which again used the measured ΔP. Results of this calculation are shown in Fig. 4.

Conclusion

The conclusions drawn from performing this comparison cannot safely be stated as applicable to all extrusion tests, since conditions may differ substantially, but certain comments may be useful as guides for similar comparisons.

1. All of the equations have the same basic form. Any differences lie in the way the original derived equation was simplified and any assumptions made by the author of the equation. Eq. A can be converted into the same form as Eqs. B and C by making a correction for flight width.
2. The test showed that using total pressure in the equations is not indicative of what is actually happening in the extruder. Although the screw obviously must develop all of the pressure, only part of it may be developed by the metering length. The authors of the simplified procedures have apparently recognized this and have used the viscosity term to compensate for it. This may account for the different values obtained. The values taken from a general purpose graph should, therefore, be used cautiously.

Viscosity can be expected to decrease with an increase in temperature, screw speed (increase in shear rate), and usually with pressure because of the resultant temperature rise. Keeping these factors in mind will help in a more accurate performance prediction. On the output versus pressure plot, the output line becomes steeper with lower viscosity and the screw output becomes more sensitive to pressure changes.

3. In the first calculation, all of the equations described drag flow quite well. Eq. A was approximately 15% higher because the width of the screw flight is not accounted for. With this correction, Eq. A would be as accurate as Eqs. B and C.

The second term in the equations (pressure flow) is more difficult to evaluate properly since it depends on pressure and viscosity. In this comparison for the first calculation Eq. B provided nearly the proper value up to about 30 rpm. Above 30 rpm, Eq. A had the most accurate value, but since the drag-flow output was too high, the output at higher pressure was somewhat high. Eq. A would have predicted output quite well above 30 rpm if all values had been reduced by 15%.

4. Using $\triangle P$ and the actual channel depth did not change the drag flow but obviously affected the pressure flow term. Eq. C was improved greatly in this calculation. This points out that the performance of the metering section depends greatly on how the rest of the screw behaves. Calculations based on the metering section alone should, therefore, be considered only as approximations limited sharply by extrusion conditions.
5. Making use of the increment in pressure ($\triangle P$) and the effective channel depth (h^*) changed all of the equations quite markedly. Eq. C provided the best approximation using the new conditions. Generally speaking, the value for h^* was about 80% of the actual channel depth.

This would indicate that if actual pressure conditions ($\triangle P$) across the metering section are known, the use of Eq. C and a value of h^* equal to 80% of actual flight depth will yield a good approximation to actual output.

It is apparent from this comparison that none of the procedures proved entirely accurate for all conditions, but it should be noted that the equations describe the qualitative way in which the output is delivered if not quite the correct quantity.

Any comparison of this type points out that the extruder prediction picture is becoming brighter all the time. The tools are now available and it merely remains for future work to make them more generally applicable.

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3. "Fundamentals of Thermoplastic Extrusion"—R. D. Sackett, *Monsanto Product Information Bulletin No. 1029*, Copyright 1956.
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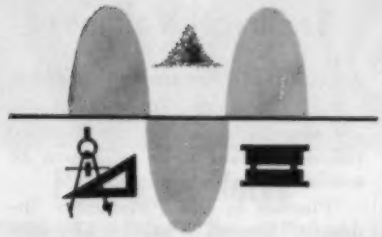


Edited by Louis Paggi, *Consultant*
E. I. du Pont de Nemours & Co., Inc.

MOLDING CYCLES

Selection of Plastifying Cylinders to Suit Requirements

Louis Paggi

Designing a plastifying cylinder for universal use could be a rather simple task if it were possible to exclude physical properties and close dimensional tolerances from the specifications of a molded article. It is becoming increasingly apparent that no cylinder of a given design will yield the best performance for every conceivable application.

Certain thermoplastics, as for example polyethylene and styrene can be molded over a wide temperature range. With these materials, the output of a cylinder can be forced by use of higher temperatures. Certain other thermoplastics, for example acrylics and nylons, cannot be molded over a wide temperature range for every application. With these materials, the output of a cylinder can be increased by design, incorporating a large surface to volume ratio. Although we may well be aware of the factors leading to the best design, we are prevented from constructing an ideal cylinder by mechanical limitations.

An ideal cylinder would accomplish the following:

1. Melt material without degrading it.
2. Deliver melt of uniform temperature.
3. Hold pressure loss to an absolute minimum.
4. Deliver the greatest quantity of melt per rated ounce capacity per unit time.
5. Be of small physical dimensions and low cost.

If we analyze the above requirements we will find that in general we can gain in one area only at the sacrifice of another. For example, output and pressure are sacrificed in order to reduce degradation. Pressure is sacrificed to improve the uniformity of melt temperatures, etc.

While equipment manufacturers are constantly working to improve the design of their product, they can remain in business only by satisfying the demand. If the demand is for greater poundage output, disregarding quality, cylinders will be designed to meet this demand.

It is only natural for the average molder to wish to obtain the maximum output from his investment. But if quantity is favored to the exclusion of quality, the expansion of the molding industry will be seriously affected. There are two reasons for this: First, the consumer is becoming increasingly aware of the properties which can be obtained with plastics. Second, the expanding family of plastics will enter many new applications which can be held only with top quality moldings.

Since the plastifying cylinder represents a relatively small portion of the total investment of a molding machine, the molder would be better equipped to handle a variety of materials and applications by investing in more than one cylinder when applicable to a given machine. Before proceeding with the selection of a plastifying cylinder for a given job, we will want to analyze performance requirements in terms of design considerations as follows:

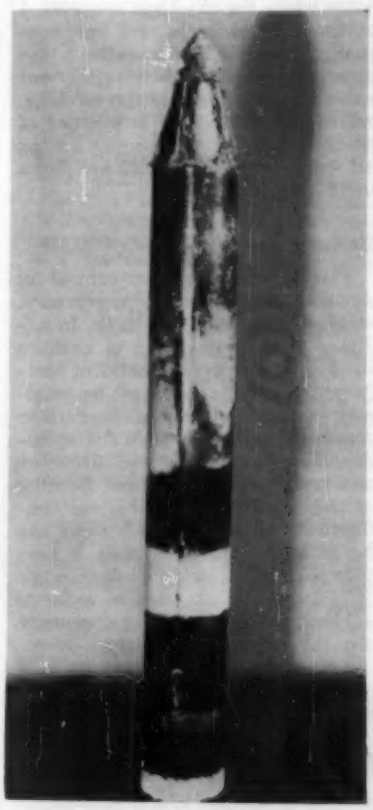
Avoid Degradation

Degradation is the result of prolonged exposure to elevated temperatures. It can occur in a relatively short time, when the temperature of the plastifying cylinder is maintained above normal levels, or it can occur over a longer period of time at normal temperature levels.

All thermoplastics are relatively poor conductors of heat; therefore, if we are to avoid degration the application of heat should be gradual.

Employing high watt-density bands and excessively high temperatures in an effort to speed the melting of the material will result in local degradation. The effect would be much the same as increasing the temperature of a frying pan in order to reduce the time required to fry eggs. Scorching or burning will result. Because of the low percentage of oxygen in a packed plastifying cylinder, discoloration may not necessarily be present, but never-the-less the material will be degraded.

Aside from the obvious causes of degradation such as forcing the output of a cylinder by the application of excessive heat and overheated sections, the chief cause of degradation is laminar flow. For practical purposes, this type of flow may be visualized as occurring in distinct layers across the melt stream with each layer flowing at a different rate than the adjacent layer and a certain amount of shearing occurring



between the layers. The relative velocity of each layer will depend on local conditions of friction and viscosity. The very thin layer of plastics adjacent to the heated surface of the cylinder will face the greatest resistance to flow and will therefore be subject to the greatest amount of degradation. To lower the amount of degradation occurring in a cylinder, we can employ relatively low temperatures and restricted passageways. The low temperature will maintain a relatively high viscosity in the melt. The restricted passageways will result in a high degree of shearing and improve the scrubbing action. The accompanying photograph of a spreader and surrounding material removed from a cylinder clearly shows the by-passing of material at the front portion of the cylinder where the overall viscosity is lower.

Note that the white material is by-passing or flowing beneath the dark layer. A restricted passageway at this area will increase the velocity thus, also increasing the apparent viscosity of the melt and minimizing this effect.

A simple test for comparing the degree of laminar flow in cylinders is to note the relative quantity of thermoplastic material required to purge the cylinder of a previous color while the machine is operated at the normal cycle and temperature. The cylinder requiring the greatest quantity of material, per rated ounce capacity of the machine, will develop the greater amount of laminar flow. Rapid purging during off cycle conditions will not be a valid test.

Uniform Temperature of Melt

This is necessary for control of dimensions, toughness, appearance, molded-in stresses and voids. In addition to the application of uniform heat on the cylinder, uniform temperature can be achieved by minimizing the thickness of the molten plastics flowing through the cylinder. Here again we can draw an analogy from the kitchen. Because of the relatively poor thermal conductivity of meat, a thick steak can be cooked quite rare while a very thin slice will quickly cook through. It is quite obvious, that in order to achieve uniform melt temperature, the thin slice is necessary.

Avoid Pressure Loss

As a general rule, basic features designed to decrease laminar flow and improve the uniformity of melt temperature result in a sacrifice of effective pressure at the mold. A certain amount of pressure loss must be accepted. It can however, be held to a minimum by eliminating features which contribute to excessive pressure losses.

The area of greatest pressure loss is at the rear or feed end of the plastifying cylinder. The greatest benefit will therefore be derived by improved design of this area.

Among the design considerations are:

(a) Increased distance between the forward-most position of the injection ram and the beginning of the spreader. This area should be heated to permit some plastifying of the material before it is fed over the spreader. The length of the preheating area need not be great to be effective. Small bore cylinders will benefit with as little as one inch while large bore cylinders would seldom require more than six additional inches.

(b) Avoiding reduction of cross-sectional area of the plastics material while it remains in the solid phase. The cross-sectional area of the material entering the channels in the spreader should be at least equal to the cross-sectional area of the face of the injection ram. A reduction in cross-sectional area for the purpose of good heat transfer is desirable only if it is allowed to take place when the material is in the melt or semi-melt phase.

(c) Providing thermal isolation at the junction of the plastifying cylinder and frame of the machine. This will be an aid toward providing a more even distribution of heat over the rear zone. Thermal isolation may take the form of insulating material or a reduction in mass or area of metal in contact with the frame.

Improve Cylinder Efficiency

An efficient cylinder need not necessarily be large in physical dimensions nor hold a large quantity of material in inventory. A high surface to volume ratio coupled with a low degree of laminar flow generally spells efficient design.

A cylinder incorporating the very best in design features can still be a poor cylinder if improperly used. The responsibility for the proper use of tools lies with the individual using them.

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Technical Volumes

New RETEC Preprints Available

Two fall RETEC Preprint Books are now for sale from the National Office and four more will soon be available:

"Plastics in the Automotive Industry," Detroit. 6 papers, 57 pages. Price to members: $2.00; non-members: $3.00.

"Plastics in Packaging," Western New England. 9 papers. Price to members: $3.00; non-members: $4.50.

Preprint books which will be available soon are:

"Epoxy Resin Symposium," Upper Midwest; "Plastics in Electronics," Golden Gate; "Advances in Injection Molding," Philadelphia; "Plastics Trends in Building and Construction," Southern California. For prices, see notice in the October issue, *SPE Journal*.

Other technical volumes also available from the National Office:

ANTEC Preprint Books

Volume IV, 14th ANTEC, Detroit. Members: $5.00; non-members: $7.50.

Volume III, 13th ANTEC, St. Louis. Members: $5.00; non-members: $7.50.

RETEC Preprint Books

"Advances in Injection Molding," Chicago, 1958. Members: $2.00; non-members: $3.00.

"Plastics for Airborne Electronics," Los Angeles, 1957. Members: $3.00; non-members: $4.50.

"Polyethylene Properties and Uses," Cleveland, 1957. Members: $3.00; non-members: $4.50.

SPE Engineering Series

Vol. 1—"Quality Control for Plastics Engineers," edited by Lawrence M. Debing. 160 pages. Members: $3.98; non-members: $4.95.

Member rates are also extended to individual members of SPI. When ordering, please state whether you are a member of SPE or SPI. Books will be mailed postpaid if money is enclosed.

Society of Plastics Engineers, Inc.
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U.S.I. POLYETHYLENE NEWS

Packaging Notes

Drawstring or Poly Bag has enabled one produce packer to cut labor costs and increase packing speeds 15 per cent. The drawstring runs through a strong, heat-sealed hem on 5-lb. bags of 2 mil polyethylene film. The closure is strong enough for the string loops to be hung on overhead conveyors or used by customers as a convenient carrying handle. The bags require less film to fabricate than do tied-top bags and they are claimed to be easier to fill. Produce shippers have expressed interest in the drawstring poly bag for packing potatoes and citrus fruit.

Polyethylene Bottle Closure with expandable plug is designed to prevent movement and breakage of pills during shipping and use. The patented closure replaces the usual cotton pad or paper insert ordinarily used with tablet containers.

The polyethylene insert is constructed to double up when the cap is screwed onto a full bottle. As pills are used the insert expands to fill the void and hold the pills in place.

Aside from convenience, the expandable closure is said to be more hygienic than cotton plugs since it is never touched in use. The inserts, used for some time by leading German pharmaceutical firms, are now being introduced in this country.

New polyethylene tablet bottle closure employs flexible insert, left, which snaps into screw cap. Insert expands to hold tablets in place even when bottle is half empty.

Two New Decorative Coatings for polyethylene have been announced recently. One is a new process for vacuum-metallizing polyethylene. Brilliant coatings result, with excellent adhesion even on such items as squeeze bottles. Alcohol-proof top coats can also be applied by the same method.

What is reported to be the first adhesive for flocking polyethylene has been announced by another manufacturer. The new adhesive makes it possible to apply a velour coating to sheet or molded products. The process is expected to find application in packaging cosmetics and quality items such as silverware.

U.S.I. Announces Crystal-Clear Poly Film Produced by Cast-Film Process

Cast PETROTHENE® Film Has Top Transparency and Gloss

A crystal-clear polyethylene film, made by a conventional processing technique adapted to polyethylene film production, was introduced by U.S.I. at the 1958 National Packaging Exposition in New York. The film, made from a U.S.I. PETROTHENE resin, has a level of transparency and gloss unprecedented in polyethylene film.

The production method, called casting, employs equipment typical of the extrusion coating industry. In the process polyethylene is extruded and drawn or cast across a highly polished chrome-plated roll. This casting step greatly improves the optical characteristics of the film. This production method also reduces formation of haze-producing crystals in the matrix of the polyethylene by providing for immediate and even quenching. This further contributes to improved clarity.

Extensive research at U.S.I.'s technical service laboratory indicated that a moderately high density resin would be required to strike a balance between properties which promote clarity and those promoting strength. PETROTHENE 205—with a density of 0.924, melt index of 3.0 and PETROTHENE 239 with a density of 0.929, melt index of 5.0 were selected.

Production Costs About Equal

Although the equipment needed for making cast film is initially more expensive, production costs appear to be competitive with those for conventional extruded film. Production speed for cast film is the same or greater than for other film producing processes.

MIRROR IMAGE? No, but the excellent clarity and gloss of cast PETROTHENE film make it almost believable. It's all done with twins.

Production on laboratory-scale equipment indicates that careful control of die temperature and size of die opening is necessary to assure gauge uniformity. However, with proper operating conditions and careful choice of resin, the resulting film has adequate toughness along with its phenomenal clarity. Widespread application in the packaging industry — where clarity is often a prime consideration — is expected.

Nitrogen Blanketing Aids Polyethylene Processing

Nitrogen blanketing of polyethylene extruder feed helps overcome gels, fish-eyes, dark spots and other problems caused by polyethylene oxidation.

The procedure was developed at U.S.I.'s technical service laboratory at Tuscola, Ill. It is based on the idea of excluding oxygen by maintaining an inert gas blanket over the resin entering and inside the machine.

According to Ralph Knight, Manager of U.S.I.'s PETROTHENE Technical Service Department, as a further refinement, inert gas also can be used to blanket the molten polyethylene as it leaves the extruder in order to reduce build-up of oxidized material on the die lips of the extruder. The same principle is applicable to other polyethylene processing methods, such as molding.

Coffee Plants Grown in Black Poly Bags

A promising new use for black polyethylene film is reported from Central America. Black poly bags filled with fertilized soil are being used to grow coffee plants in Guatemala. The film acts as a combination flower pot and mulch.

According to the report, when plants are grown in polyethylene bags, they can be brought to transplanting size in nine months instead of the 18 months formerly required. In 1957, approximately seven million polyethylene bags were used in Guatemala.

1.5-mil cast polyethylene film made from PETROTHENE 239-27 resin has unprecedented clarity and gloss.

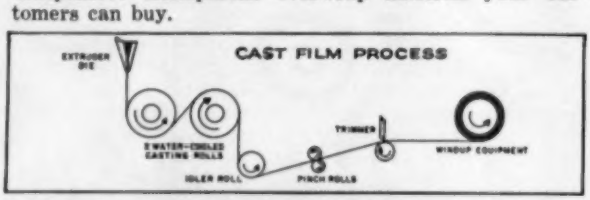
CAST POLYETHYLENE FILM
NOW OUTDATES OTHER TRANSPARENT PACKAGING MATERIALS

Cast polyethylene film—made by a special process employing U.S.I. PETROTHENE® resins—enables you to offer your customers the traditional strength and economy of polyethylene—plus sparkling clarity and gloss. Here's why cast film far surpasses other overwrap materials:

CRYSTAL CLARITY—The new process for making cast polyethylene film produces material with a clarity equal or superior to conventional transparent films. Compare a piece of cast film with ordinary polyethylene film and with transparent films now used for overwrap.

SUPERIOR PACKAGING PROPERTIES—Cast polyethylene film has good impact and tear strength, high grease resistance and is an excellent moisture barrier. It heat seals well and is easily printed. The film doesn't crackle; it has a soft, natural flexibility that adds a look of quality to packaged goods. And handles well in overwrap machinery designed for conventional polyethylene film.

ECONOMY—You can offer your customers substantial savings with cast polyethylene film. It costs less than conventional transparent materials—whether you figure costs per pound or per unit area of film. It is the most inexpensive transparent overwrap material your customers can buy.



To extruders interested in manufacturing cast polyethylene film, U.S.I. will be glad to furnish technical assistance. Contact your nearest U.S.I. office, or write:

USI DUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N. Y.
Branches in principal cities

U.S.I.

Vol. III, No. 4

POLYETHYLENE PROCESSING TIPS

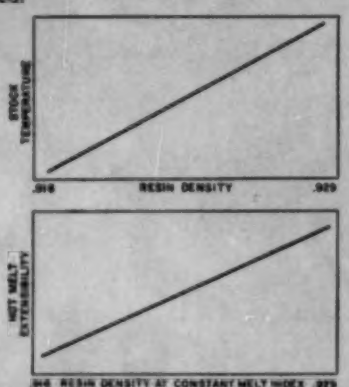
HOW RESIN DENSITY AFFECTS FILM PROPERTIES, EXTRUSION CONDITIONS

Extruders of blown or flat film will find, in working with some of the newer polyethylene resins of about .93 density, that they are significantly different from the more conventional resins of about .92 density—both in behavior during processing and in properties of the final film.

Operating Temperatures and Speeds Rise

As resin density increases from .916 to .930, higher stock temperatures are required—ranging from zero to 30°F higher, depending on the resin. At the same time, blown film does not have to be cooled as much. Since the higher density resins have a harder surface, are less tacky, and do not block readily, the temperature of a film of .930 density resin can be 10-20°F higher at the nip rolls of the take-up without introducing internal blocking.

The higher film temperatures at the pinch rolls help prevent wind-up wrinkling to which higher density films are susceptible (see U.S.I. Polyethylene Processing Tips, Vol. III, No. 3). Less cooling means faster production using higher density resins, and is also advantageous when space for cooling equipment is limited.



It should be remembered, in processing higher density resins, that the resulting films have lower impact strength than do films from lower density resins. Therefore, excessive roll pressures in blown film wind-up should be avoided, to prevent too sharp a crease in the flattened film cylinder, particularly in gussetted film. A sharp crease, when subjected to impact loading during film use, will frequently fail by tearing.

Also, as density increases from .916 to .930, resins have better hot melt extensibility—can be drawn down to thinner gauges. U.S.I.'s .929 density resin, for example, has been drawn down to less than 0.2 mils thickness in a regular production run.

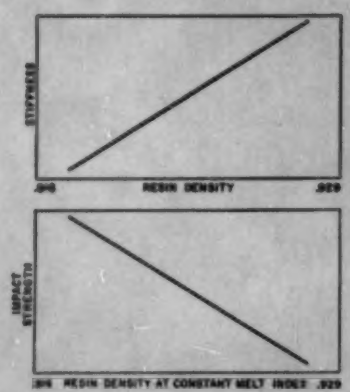
Films are Stiffer, Easier to Handle: Seal Hotter

Films extruded from higher density resins have more body and less stretch than do those made from conventional resins. This means that they are easier to handle on standard converting equipment and can be more easily used on high-speed converting and packaging machinery.

In heat sealing, as in extrusion, slightly higher temperatures must be used to effect a satisfactory seal with the higher density resins.

Clarity Up, Impact Strength Down

At resin densities of about .93, films are clearer, have less haze, higher gloss, greater transparency. They are stiffer, with more tensile strength, but have lower impact tear and impact strengths. Because they have harder surfaces, they are more abrasion-resistant. Heat resistance also increases. Permeability goes down (see U.S.I. Polyethylene Processing Tips, Vol. II, No. 2).



As you can see, the extruder's choice of resin density will depend largely on the film properties desired by his customer. For toughness, flexibility and good protection, low densities are indicated. For more stiffness, clarity and heat resistance, higher densities are coming into prominence.

U.S.I. offers a series of polyethylene resins, ranging in density from .916 to .929. U.S.I. technical service engineers can recommend the proper resin with the best balance of properties for your particular application. They will be glad to work with extruders and converters on processing problems as well.

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N.Y.
Branches in principal cities

PETROTHENE

FILM EXTRUSION

APPLICATION	GAUGE (mil)	ESSENTIAL PROPERTIES	recommended PETROTHENE RESINS
GARMENT BAGS	0.5 to 0.75	High draw-down, good clarity, high gloss, resistance to blocking, good slip.	207, 239
SOFT-GOODS BAGS	0.75 to 1.25	High draw-down, high clarity, good gloss, resistance to blocking, good slip.	208, 207
PRODUCE BAGS			
SMALL	1 to 1.25	Moderate toughness, clarity, gloss, resistance to blocking, good slip.	206, 210
LARGE	1.5 to 2	Higher toughness, fair clarity, gloss, resistance to blocking, good slip.	200, 205, 210
CHEMICAL PACKAGING BAGS	1.5 to 3	Toughness, resistance to blocking, good slip.	200, 204
CONSTRUCTION AND ARCHITECTURAL	4 to 8	Extreme toughness.	200, 301

FILM EXTRUSION — (cast and quenched)

SOFT-GOODS BAGS	0.4 to 0.75	High draw-down, clarity, gloss, resistance to blocking, good slip.	239
OVERWRAP	0.75 to 2	Clarity, gloss, resistance to blocking, good slip.	239
PRODUCE BAGS	1 to 2	Moderate toughness, clarity, resistance to blocking, good slip.	200, 205, 210
CONSTRUCTION AND ARCHITECTURAL	4 to 6	Extreme toughness.	200, 301
AGRICULTURAL (MULCH)	0.75 to 2	Moderate toughness, high draw-down.	201-216
	2 to 6		102, 102-216
PIPE EXTRUSION		NSF approved for potable water	102-216
		Nonpotable water supplies	550-218
CALENDERING			102, 102-216

PETROTHENE TYPES RECOMMENDED for different applications

USE	ESSENTIAL PROPERTIES	recommended PETROTHENE RESINS
PAPER COATING	Good draw-down, freedom from odor, good adhesion, grease proofness, heat sealability	
	Best draw-down	207, 239
	High resistance to permeability	100, 239
	Minimum "neck-in"	100, 200
	Balanced properties	205, 210
WIRE AND CABLE COATING	Excellent dielectric properties	
	Excellent resistance to environmental stress cracking	
	High frequency insulation	300-6
	Wire and cable jackets, where unusual stress crack conditions are encountered	300-200
	Primary insulation for telephone cables, general insulation where color coding is required	300-Color Code
	Good resistance to environmental stress cracking	
	High frequency coaxial cables; primary insulation for telephone cables, multi-conductor control cables, power cables	301-6
	Weather resistant wire and cable; neutral supported secondary and service drop cable	301-200
	WD1/TT infantry field wire	301-202
	Primary insulation for telephone cables; general insulation where color coding is required	301-Color Code
	General-purpose applications	
	Non-critical, non-specification insulation	302-6
	TV antenna lead-in wire	302-506
INJECTION MOLDING	Fast flow, maximum stiffness	
	Size:	
	Very large (>20 oz)	208, 241
	Very large (>20 oz), high resistance to low-temperature brittleness and shattering	202
	Large (10 to 20 oz)	202, 203, 207, 208
	Small (6 to 10 oz)	201, 203, 206, 207, 239
	Very small (<6 oz)	220, 204, 205
	Best transparency and gloss	207, 208, 241
	Best freedom from warp (low level of locked-in stresses)	202
BOTTLE BLOWING	Best appearance	102, 208
	Highest environmental stress cracking resistance	301
THERMOFORMING	Stiffness, chemical resistance, low water absorption	205, 239
	Maximum resistance to sag	239, 301
	High stiffness and thin walls	239
	Optimum toughness and great flexibility	301
	Good balance of end properties	205

FORM: Solid cubes approximately ⅛" on a side.
COLOR: All PETROTHENE types are available in various colors as well as natural.
PACKAGING: Polyethylene coated multi-wall bags; net weight 50 lbs.; 1500 lbs. and 9000 lbs. U. S. Rubber Sealdoms. Palletized shipments upon request.
MINIMUM ORDER: 50 lbs.
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Edited by Thomas A. Bissell
SPE Executive Secretary

NATIONAL ACTION

Members' Responsibility in Choosing Councilmen

In nominating and electing National Councilmen this fall, members in many Sections face a responsibility that profoundly affects our Society's future.

Since any organization is a direct reflection of the men who manage it, SPE's influence and prestige in the plastics industry are determined largely by the calibre of its National Councilmen.

Before nominating or electing a National Councilman, it is fitting that members pause and ask: What qualifications should a Councilman bring to his assignment?

To venture one opinion, to serve his Society best, a National Councilman should:

1. Have been active in the Society at either or both Section and National levels long enough to become thoroughly familiar with operations, policies and problems.

2. Think and act objectively for the general good of the entire Society, rather than merely representing his Section's special interests.

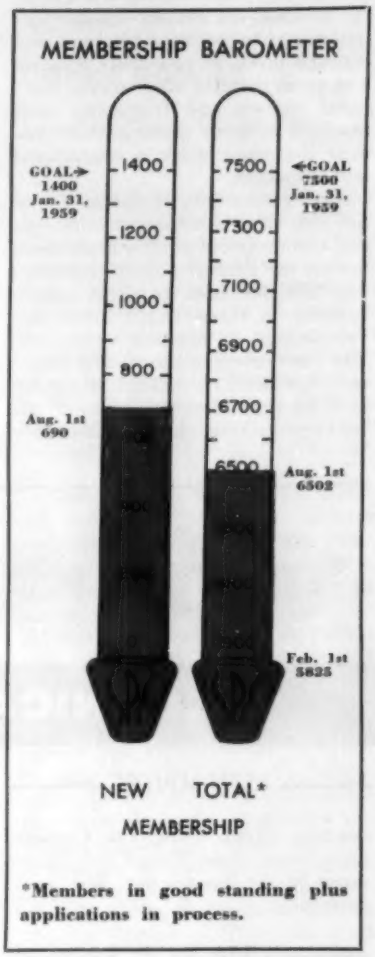
3. Be free to travel to four Council meetings annually, and to devote several hours per week in the interim to Society affairs.

4. Have demonstrated his leadership by rising to a position of eminence related to plastics science and engineering.

Sincerely yours,

Thomas A. Bissell

Thomas A. Bissell
Executive Secretary



***Members in good standing plus applications in process.**

Sputnik and You

SPE Educational Activities Benefit Students, Teachers and Individual Members

In spite of world-wide clamor for improved education, we, as SPE members, may have difficulty in understanding our responsibilities and role in this basic activity.

Sputnik crystallized the plight of our nation's education. It brought home the need for upgrading educational standards and enlarging the pool of trained people needed to advance economic and technical progress. In today's shrinking world, we are forcefully confronted, whether we like it or not, with the realization that science and engineering constitute vital threads in the fabric of the world's society. If a synthetic satellite had not focused our attention sharply on this aspect of today's living, some other incident would have done so. We are fortunate to have had this need for advance in education brought forcefully to our attention.

The responsibility of SPE and each one of us as individual members in this important task falls into three areas of activity—student, teacher and personal education.

When we consider making an educational contribution, we usually think first of the student, the product of the activity. Much can be done to assist students—by guidance, stimulation of interest, financial assistance, enlargement of physical equipment for education, promotion of higher scholastic achievement, and by other ways too numerous to mention.

Many fertile fields for educational activity also exist in working with teachers. Teaching is a most honorable and necessary profession; yet it is the most underpaid. Although progress has been made recently in promoting financial assistance to students, there have been more words than action in raising the pay levels of the teaching profession. There may be little that our Society can do in the line of financial assistance for teachers, but there is much that we, as individuals, can do to encourage them and to make them realize that their importance is recognized. Paralleling existing parent-

teacher organizations, there is a need for professional society-teacher relationships to serve the teachers, encourage them, elevate their prestige and assist them in other ways. Personal contact and friendship with teachers help in making them realize that their work is appreciated and respected.

After graduation, education should not stop. For personal advancement and attainment of greater proficiency within the field of plastic engineering, SPE provides excellent opportunities to learn about latest developments in plastics technology. The various committees, *SPE Journal*, ANTECS, NATECS, RETECS and Section Meetings provide the best opportunities for every member of our Society to keep his knowledge of plastics science and engineering up to date. Rapid changes and new developments in plastics require a proficient plastics engineer or scientist to devote constant attention to his own education. Exchange of technical information about advancements in plastics by members is vital to such training. In this third area of education for the individual members of SPE, rapid progress has been made during the last five years. Everyone who has contributed to this healthy trend deserves recognition and praise.

From the foregoing discussion it can be seen that SPE educational activities have one characteristic in common—that success or failure of these programs, in the final analysis, depends upon the individuals themselves working in harmony with the various groups in SPE. Our Society provides many opportunities for deep personal satisfaction in individual and collective work in educational activities. It is the responsibility of all SPE members to contribute to the educational needs of our Society, our nation and mankind.

Robert C. Bartlett

R. C. Bartlett, Chairman
SPE National Education Committee

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TECHNICAL MEETINGS CALENDAR

15TH ANTEC

January 27-30, 1959, The Commodore Hotel, New York City. Sponsored by the Newark and New York Sections.

1958 RETECS

PLASTICS IN THE AUTOMOTIVE INDUSTRY—September 12, 1958, St. Clair Inn, Detroit, Mich. Sponsored by the Detroit Section. For information contact John D. Young, E. I. du Pont de Nemours & Co., Inc., 13000 W. Seven Mile Rd., Detroit, Mich., or R. C. Oglesby, Rohm & Haas Co., The Nor-Way Bldg., 20211 Greenfield Rd. at Jas. Couzens Hwy., Detroit 35, Mich. *(See SPE Journal, August 1958, p. 45.)*

PLASTICS IN PACKAGING—October 1, 1958, Statler Hotel, Hartford, Conn. Sponsored by the Western New England Sections. For information contact Blakely McNeill, Fuller Brush Co., 3580 Main St., Hartford 15, Conn. *(See SPE Journal, August 1958, p. 47.)*

EPOXIES—October 21, 1958, Curtis Hotel, Minneapolis, Minn. Sponsored by the Upper Midwest Section. For information write to Russ Kirby, Minnesota Mining and Manufacturing Co., 900 Farquier, St. Paul, *Minn. (See Program, p. 65.)*

PLASTICS IN ELECTRONICS—October 24, 1958, Stanford Research Institute, Menlo Park, Calif. Sponsored by the Golden Gate Section. For information write to Julius W. Palen, Lenkurt Electric Co., Inc., San Carlos, Calif. *(See Program, p. 67)*

ADVANCES IN INJECTION MOLDING—November 6, 1958, Sheraton Hotel, Philadelphia, Pa. Sponsored by the Philadelphia Section. For information write to Edward Fitzpatrick, F. J. Stokes Machine Co., Olney Post Office, Philadelphia, Pa. *(See Program, p. 68.)*

PLASTICS TRENDS IN BUILDING AND CONSTRUCTION—November 13, 1958, Ambassador Hotel, Los Angeles, Calif. Sponsored by the Southern California Section. For information write to John Delmonte, Furane Plastics, Inc., 4516 Brazil St., Los Angeles, Calif. *(See Program, p. 71.)*

1959 RETECS

(Scheduled before June 1959)

PLASTICS IN THE SHOE INDUSTRY—April 21, 1959, St. Louis, Mo. Sponsored by the St. Louis Section. For information write to Robert S. McDorman, Plastics Molding Co., 4211 N. Broadway, St. Louis, Mo.

PLASTICS IN THE METAL INDUSTRY—May 7, 1959, Penn-Sheraton Hotel, Pittsburgh, Pa. Sponsored by the Pittsburgh Section. For information write to John Parks, Hydraulic Press Mfg. Co., 512 Empire Bldg., Pittsburgh 22, Pa.

SECTION MEETINGS

NEW YORK—September 17, 1958, Governor Clinton Hotel, New York City. "Plastics in Russia" is the subject of a talk by Clinton W. Blount, Bakelite Co., who will show slides of his recent trip to Russia. William Nausbaum, C.P.A., will speak on "Cost Analysis for the Plastics Molder." SPE National President and other National Officers will participate.

NORTHWEST PENNSYLVANIA — September 25, 1958, Sportsmen's Athletic Club, Erie, Pa. "The Uranium Industry" will be the subject of a talk and movie presented by Robert J. Klatzbach, manager, chemical processes, Union Carbide Nuclear Co., Div., Union Carbide Corp. Dinner at 7:15 P.M.; program at 8:30 P.M.

COMMITTEE REPORTS

Plastics in Buildings PAG To Hold Washington Meeting

The Professional Activities Group on Plastics in Buildings (PAGPIB) has planned three initial projects to implement their aim of "increasing the quantity and quality of technical information which would be useful to persons employing plastics in buildings." As indicated by the name of this group, its activities will be concerned with those plastics used either as a permanent part of the structure or employed during construction. Briefly, these projects are: (1) the preparation of a PAGPIB catalog of plastics products used in building and buildings to provide architects, engineers and builders technical engineering data and other information on commercially available products composed either wholly or primarily of plastics materials; (2) the preparation of a list, table, directory or dictionary of standard plastics terminology and interpretation of these terms in language for laymen in the building industry; and (3) the preparation of literature surveys, technical abstracts or technical reports on specific subjects within the scope of the group for dissemination to the building industry.

On July 17, 1958, the author attended a special meeting of the Building Research Institute Plastics Study Group Planning Committee which had invited representatives of the SPE, SPI, ASTM D-20 and the Manufacturing Chemists Association to discuss the planned activities of each of these organizations in the field of plastics in buildings. Other organizations such as the Southwest Research Institute, the American Institute of Architects and the National Association of Homebuilders were represented by regular members of the planning committee. PAGPIB plans, as outlined above, received the wholehearted blessings of the groups represented at this meeting. Based on comments received, the need for this type of activity definitely exists in the industry. Cooperation among such groups should assist in making PAGPIB activities successful.

It is recognized that such a program is a very ambitious undertaking for such a newly-organized group. Certainly, the members of SPE will want to make every effort to help Professional Activities Groups become successful in their various fields and to gain recognition in the plastics industry. This can only be accomplished through active participation in PAG programs.

Professional Activities Groups are working technical groups. As such, the PAGPIB will welcome participation in its activities by those many SPE members who have an interest in seeing this and other group work carried out successfully, but who have not yet made known their willingness to participate. The next meeting of the PAGPIB is planned for 10:00 A.M., Wednesday, October 1, 1958, National Bureau of Standards in Washington, D.C. Following reports on their investigations by the temporary chairmen for each project, permanent project chairmen and committees will be established and programs planned. All interested SPE members are urged to attend. Local Sections having sufficient members interested in pursuing a PAGPIB project as a Section activity are requested to have a representative in attendance. Those planning to attend are asked to advise Frank W. Reinhart, Plastics Section, National Bureau of Standards, Washington 25, D.C., as early as possible so that adequate arrangements can be made for meeting rooms and a tentative agenda with meeting place can be mailed to participants. Your suggestions will be welcomed at any time.

Donald R. Gray
Chairman, PAGPIB

ASTM— Cellular Materials Coordinating Committee

The major function of this group has been the assignment of work to various ASTM Materials committees and the coordination of the work of these committees. The principal problem has been the delineation between rubber and plastics. In other words, where shall flexible organic cellular materials be placed, in D-11 on Rubber or in D-20 on Plastics? The general policy was defined on January 8, 1957 as follows:

"Responsibility for basic test methods and specifications for cellular materials is assigned to ASTM Committees D-11 on Rubber and Rubber-like Materials and D-20 on Plastics. Committee D-11 is responsible for cellular materials made from rubber and rubber-like materials having properties similar to those described in specifications and tests for latex foam rubber (D 1055-56 T) and for sponge and expanded cellular rubber products (D 1056-56 T). Committee D-20 is responsible for cellular materials made of plastics excluding rubber and rubber-like materials. Responsibilities for cellular materials for specific applications are assigned to Committees C-16 on Thermal Insulating Materials, C-19 on Structural Sandwich Constructions, C-20 on Acoustical Materials, D-9 on Electrical Insulating Materials, and D-10 on Shipping Containers, within the limitations of their scopes.

"In cases of overlapping interests between two committees they shall attempt first to agree on a mutually acceptable division of work. If unable to agree, the problem shall be submitted to the Coordinating Committee.

"Exchange of information (minutes) through the Coordinating Committee will reveal areas of overlapping interest so that differences may be discovered and resolved promptly."

The Coordinating Committee requested that both D-11 and D-20 submit a definition for "Rubber-like materials" to them. The Advisory Committee of D-20 submitted the following definition on February 25, 1958, to Dr. J. E. Gaston, Chairman of the Coordinating Committee:

Rubber and rubber-like materials —natural or synthetic materials that

can be or are already vulcanized to a state in which they have high extensibility and forcible quick retraction. This definition paraphrases the definition for "Rubber" in D 883-56T. The definitions for "Elastomer, Plastic, and Vulcanization" in D 883-56T are also applicable.

Another problem naturally develops from the above definitions as follows: In the examination of a material to determine whether or not it is "rubber and rubber-like material," should a solid piece of the material be examined or should a piece of foam be examined? In other words, should the geometry of the specimen be a factor in arriving at a decision? It was decided that a solid piece of the material should be examined to determine whether or not it is rubber-like.

In the meantime, ASTM Committee D-11 has been working on all types of flexible cellular materials. The group in D-20 has been working on rigid cellular materials and waiting for a decision regarding assignment of flexible materials. No assignments have been made to date.

Since it is difficult to work only on rigids, ASTM Committee D-20 requested the ASTM Board of Directors on June 25, 1957, to form a new ASTM Committee on Cellular Materials. This request was not granted but the problem was turned over to the Coordinating Committee. The request to form a new ASTM Committee on Cellular Materials will be made to the Coordinating Committee at the next meeting.

Frank W. Reinhart
SPE Liaison Chairman,
ASTM Cellular Materials
Coordinating Committee

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Plastics and Rubber Symposium

Sponsored by the Instrument Society of America
Sheraton-Mayflower Hotel, Akron, Ohio
October 20 and 21, 1958

Under the guidance of Frank Martin, Chairman of Inter-Society Relations with ISA, SPE works closely with ISA in planning technical activities. For this reason SPE members are given ISA member registration rates at this conference.

Registration will be $8.00 for ISA and SPE members, $12.00 for non-members. The fee includes a copy of the published proceedings. Further information may be obtained from David R. Davis, General Tire & Rubber Co., Akron, Ohio.

Monday, October 20

8:00 A.M.—Registration

9:00 A.M.—Keynote Address—James E. Trainer, *Executive Vice-President, Firestone Tire & Rubber Co.*

10:00 A.M.—"Nuclear Magnetic Resonance and the Structure of Polymers"—Dr. Richard H. Sands, *Asst. Professor of Physics, University of Michigan.*

11:00 A.M.—"Base Line Control in Gas-Liquid Chromatography"—Lloyd V. Guild, *Vice President, Burrell Corp.*

12:00 Noon—Luncheon

1:00 P.M.—"The Measurement of the Rheological Properties of Polymers"—Walter T. Blake, *Vice President, C. W. Brabender Instruments, Inc.*

2:00 P.M.—"Nuclear Magnetic Resonance and Its Applications to Polymers"—Dr. R. S. Codrington, *Schlumberger Corp.*

3:00 P.M.—"Applications of Gas Chromatography"—H. N. Claudy, *Perkin-Elmer Corp.*

4:00 P.M.—"Applications of Infrared Analyzers"—L. E. Mailey, *Mine Safety Appliance Co.*

Tuesday, October 21

8:00 A.M.—Registration

9:00 A.M.—"Nuclear Measurements and Process Control in the Rubber Industry"—George V. Doering, *Industrial Nucleonics Corp.*

10:00 A.M.—"Application of Automatic Data Handling to the Rubber and Plastics Industry"—J. T. Teed, *Minneapolis - Honeywell Regulator Co.*

11:00 A.M.—"High Frequency Dielectric Heating and Drying of Rubber and Plastics"—W. H. Hickok, *The Girdler, Corp.*

12:00 Noon—Recess

1:00 P.M.—"Programmed Control as Applied to Aircraft Tire Testing"—Harold P. Lamb, *Adamson-United Co.*

2:00 P.M.—"Differential Transformer Gaging in the Rubber and Plastics Industry"—W. D. Macgeorge, *Automatic Timing & Controls, Inc.*

3:00 P.M.—"Fundamentals of Weighing and Recent Developments"—Robert E. Bell, *Toledo Scale Co.*

RETEC

Epoxy Resin Symposium

Sponsored by the Upper Midwest Section
Curtis Hotel, Minneapolis, Minn.
October 21, 1958

8:00 A.M.—Registration, Curtis Hotel Lobby
(Advance Registration arrangements may be made with James C. Stuebner, Rohm & Haas Co., 533 Metropolitan Bldg., Minneapolis, Minn. Fee: SPE-SPI members—$6.50; Non-members—$7.50. Registration fee includes luncheon and preprint book.)

Morning Session

9:30 A.M.—"Relation of Chemical Structure to Properties of Some New Epoxy Resins"—D. D. Applegath, *Dow Chemical Co.*
There is a definite correlation between the functionality of an epoxy resin and its physical properties in the cured state. This paper discusses the properties, performance and increasing functionality of Dow epoxies.

10:05 A.M.—"Dynamic Mechanical Properties of Epoxy Resins"—D. H. Kaelble, *Minnesota Mining & Mfg. Co.*
Dynamic mechanical response surfaces are discussed in terms of molecular chemistry and physics, and correlations are drawn concerning mechanical properties measured by standard test techniques.

10:40 A.M.—"Techniques of Evaluating Epoxy Foams"—C. L. Segal, *Hughes Aircraft Co.*
Standard and special methods were used to evaluato the electrical, mechanical, thermal and physical-chemical properties of two types of epoxy foam. One of the foams was designed for encapsulation of electronic components; the other was intended as a high-temperature structural material.

11:15 A.M.—"The Effect of Chlorine Content on Electrical and Physical Properties of Cured Epoxy Resins"— W. J. Belanger and S. A. Schulte, *Jones-Dabney Co.*
To determine the effect of residual chlorine content on epoxy resins on physical and electrical properties of cured resins, four liquid epoxies of the bisphenol/epichlorohydrin type were prepared, cured and tested.

12:30 P.M.—Luncheon
Principal Speaker—*To be announced.*
"Progress and Goals of our National Society"—R. K. Gossett, *SPE National President.*

Afternoon Session—Section A

2:00 P.M.—"The Olefin and Terpine Oxides—Novel Reactive Diluents for Epoxy Resin Formulations"—Ralph J. Gall, John J. Rizzo and Harry M. Castrantas, *Becco Chemical Div., Food Machinery and Chemical Corp.*
The olefin and terpine oxides are new and different types of reactive diluents for epoxy resin formulations. Preparation, properties and performance are discussed.

2:45 P.M.—"Low Melting HET-Hexahydrophthalic Anhydride Mixtures as Hardeners for Epoxy Resins"—C. S. Ilardo and B. O. Schoepfle, *Hooker Chemical Corp.*
Anhydride curing systems for epoxy resins are finding increased industrial acceptance because of their low toxicity and excellent electrical properties, particularly at high temperatures and under conditions of high humidity.

3:30 P.M.—"Optimum Conditions for Curing Methyl Nadic Anhydride-Epoxy Casting Resins"—Hans K. Weiss, *National Aniline Div., Allied Chemical Corp.*
The conditions under which anhydride-epoxy resin systems are cured have a distinct effect on physical and chemical properties. The effects of variations in gel time and temperature, anhydride to epoxy ratio, amount of catalyst and post cure time and temperature are summarized.

Section B

2:00 P.M.—"Properties of Epoxy Adhesives at Elevated Temperatures"—E. W. McGuiness, *Laboratory for Electronics, Inc.*
This is a progress report of tests made on commercial materials. These tests consist of shear strength measurements made on single lap aluminum specimen.

2:45 P.M.—"Dielectric Constants and Dissipation Factors of Epoxy Resins During Polymerization"—John Delmonte, *Furane Plastics, Inc.*
The dielectric constants and dissipation factors of representative epoxy resins are plotted over a frequency spectrum of 60 cycles to 10 megacycles. Changes are observed in viscosity as well as electric parameters, as polymerization ensues.

3:30 P.M.—"The Formulation of Versamide-Epoxy Plastic Soldiers for Automobiles"—D. E. Peerman and D. E. Floyd, *General Mills, Inc.*
This is a study of the relationship between the formulation of an organic solder and its subsequent performance in critical physical tests which are applied to the finished product.

RETEC Committee

Members of the RETEC Committee are: Chairman and Publicity: Russell B. Kirby, Jr., *Minnesota Mining & Mfg. Co.;* Registration: James C. Stuebner, *Rohm & Haas Co.;* Program: Luther Bolstad, *Minneapolis-Honeywell Regulator Co.;* Printing: Omar D. Brown, *Minnesota Mining & Mfg. Co.;* House: John B. Baird, *Minnesota Plastics Corp.;* Treasurer: Victor E. Hanson, *Minneapolis-Honeywell Regulator Corp.;* Ex Officio: Cort G. Platt, *Midland Galvanizing Corp.;* Paul C. Becker, *Minneapolis-Honeywell Regulator Co.;* Jerome L. Formo, *Minneapolis-Honeywell Regulator Co.;* Donald C. Brekke, *Minnesota Plastics Corp.*

Hotel Accommodations

Arrangements for hotel accommodations may be made directly with the Curtis Hotel, Minneapolis, Minn. Please state that you plan to attend our SPE RETEC.

SPE SECTION NEWS

Rocky Mountain

Epoxies in Aircraft

John Lindsay

The Rocky Mountain Section held a well-attended dinner meeting on July 17 at the Oxford Hotel, Denver.

R. M. Maybee, Technical Services Representative for the Shell Chemical Corp., spoke on the "Uses of Epoxy Resins in Structural Aircraft Components" and answered many questions on the subject. As an added attraction, A. R. Morse, of Injection Molders Supply Co., outlined the talk he will present at the 15th ANTEC next January. The subject of this talk is "The Development of the New Injection Molders Supply Vented Reverse Flow Heating Cylinder." Mr. Morse stated that the new heating cylinder eliminates many molding difficulties common to thermoplastic articles.

Newark

Outing and Banquet

F. W. Ducca

The 1957-58 season ended with a bang in the form of an outing at the Forsgate Country Club in June. The day was opened in perfect weather on the 18-hole course with a 300-yard drive by Section President Ernie Csaszar.

For those who could not maintain Ernie's pace, there were ping pong, softball and egg throwing contests. The last contest, incidentally, was won by Ed Rowan and Tony Taluba of Parkway Plastics, Inc.

The day wound up with a banquet at which 200 were present. The following golfing prizes were awarded: low score—Z. Crocker, Nixon Nitration, (score 77, par 71); closes to hole—Frank Ryk, Park Plastics; longest drive—Don Sonenberg, Phillips Chemical.

The Section is looking forward to a very busy '58-'59 season. The new Program Chairman, Jack O'Brien of Shaw Insulator Co., is assembling an interesting program of speakers for the monthly meetings. Allen Searle, also of Shaw Insulator, and Chairman of the Education Committee, is working actively with the Newark College of Engineering on a series of course in plastics. As far as future activities are concerned, the biggest event for the Newark Section is the 15th ANTEC sponsored jointly with the New York Section.

New York

Styrene/Polyethylene —Which, When, Why?

Charles C. Orr

The last meeting before the summer recess took place June 18 at the Governor Clinton Hotel. The vinyl subgroup, meeting for the second time, again drew a substantial and interested audience.

At the general meeting, Robert A. McCarthy, Monsanto Chemical Co., spoke on "Impact Polystyrene—Workhorse of the Industry." He discussed impact styrene's main advantages—economy, variety of permissible fabrication methods, and availability of many types for different applications.

Maurice T. Bolmer, Bakelite Co., discussed "Polyethylene—Variety of Properties and Products." He pointed out the two key variables in basic polyethylene structure—length of chain and length and number of branches—and how these variables change the properties of the material.

Addressing the reinforced plastics subgroup, Mrs. H. R. Merriman of Bloomingdale Rubber Co. spoke on "Structural Adhesives for Metals." She discussed the history and development of structural bonding and the physical properties and applications of adhesives.

Substituting for J. L. Been, Rubber and Asbestos Corp., James A. Houle delivered the scheduled lecture on "Structural Adhesives—Their Character and Manufacture." The discussion included an outline of the basic concepts of adhesive formulations as well as the general relationships between available raw materials and physical properties of the adhesive.

Kentuckiana

Section Divides in Two

R. O. Carhart

A meeting of the Section Directors and Committee Chairman was held on Tuesday evening, July 22, at the Mason Dixon Room, Louisville. It was announced that National Council had approved the charter for a new Section in the Evansville, Indiana, to be known as the Tri-State Section. Its charter members will be 17 from the Evansville area who have transferred from Kentuckiana.

The details involved in accomplishing this division were discussed and the necessary plans made. In the fall, the Tri-State Section will hold regular meetings in the Evansville area, and the Kentuckiana Section will hold its regular meetings in Louisville.

Ontario

Fishing Tournament

Harry Watson

Thirty-six members of the Ontario Section and their guests took part in the annual fishing tournament at the Great Lakes fishing grounds, Midland, Ontario. The fishing trophy was won by Don Halbert, F & H Plastics, Ltd. Charles L. Seay, who organized the safari, reports that Champion Halbert brought in an eleven-pound pike using the boat anchor for a hook and a quarter-pound piece of cold pork as bait. The prize for hauling in the biggest bass of the day went to Julius Mate, Detroit Mold Engineering, for a healthy, fighting two-pounder.

Four chartered boats took the contestants to the fishing grounds where more than 100 fish were brought in. Prizes of picnic coolers were drawn by John Bigelow, Wally Cannon, Graham Rea and Roy Wilson.

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RETEC

Plastics in Electronics

Sponsored by the Golden Gate Section
Stanford Research Institute, Menlo Park, Calif.
October 24, 1958

Technical Papers

"Influence of Curing Agents on the Electrical Properties of Epoxies"—John Delmonte and Kenneth D. Cressy, *Furane Plastics, Inc.*

The electrical properties of cured epoxy resins show a pronounced dependence upon the character of the curing agent. Frequency spectrum of dissipation factor and dielectric constant are presented for various aliphatic and aromatic amines at different concentrations. Additional influences of contaminants in the curing agents on electrical properties are also presented.

"Molded Plastics for the Electronics Industries"—John G. Robb, *American Molding Co.*

This is a discussion of materials, design considerations and specifications for the electronics engineer engaged in designing plastics molded parts to serve as components on new designs or to simplify manufacturing methods and reduce costs by redesigning existing parts. Advantages and disadvantages of plastics materials are discussed.

"Foams in Electronics"—Roger Jennings, *Polytron Corp.*

The problems of reliability without weight penalty which now faces the electronics design engineer has been considerably alleviated by the use of the various foamed plastics available, particularly the thermosetting foamed-in-place materials derived from epoxy, silicone and polyurethane resins. In densities as low as 2 or 3 pounds per cubic foot, these foams have demonstrated ability to withstand extreme vibration, shock loading, thermal cycling and other dynamic environmental factors encountered in combat electronic equipment.

"Thermoset Laminated Plastics in Electronic Applications"—Paul V. Brown, *California Fabricon Products.*

Thermoset laminated plastics have been used as electrical insulation in ever-increasing quantities due to their versatility and inherent characteristics. The need for functional reliability and insulating materials used in the increasingly critical and complex electronic gear is rapidly disclosing the need for more thorough knowledge of the relationship between physical and electrical characteristics of insulating materials.

"Plastics and Their Applications in Business Machines"—Rudolph Lorenz, Jr., *International Business Machines Corp.*

The types of materials selected and their method of fabrication are extremely important in producing close tolerance parts for business machines. Typical parts and their associated problems will be presented. Current problems and material needs which are yet to be filled will also be discussed.

"Electronics Modularization Through Plastics"—Dan G. Haney, *Lenkurt Electric Co.*

The use of plastics in electronics need not be limited to providing moisture barriers, resistance to breakage or superb electrical properties. One of the most promising applications is in the reduction of manufacturing costs through automatic assembly and packaging methods.

"Polymer Composition for the Electronic Engineer"—Charles L. Petze, Jr., *Delaware Research & Development Corp.*

This paper cites the properties of plastics compositions used in electronic equipment. Examples are given of the reliability of plastics parts used for several years in radio and radar installations for submarines and aircraft.

"Silicone Applications in the Electronic Industry"—Donald F. Christensen and Kenneth R. Anderson, *Dow Corning Corp.*

Material selection is one of the most important considerations when designing components and assemblies for the wide range of service conditions demanded of electronic systems. Because of their unique combinations of thermal, physical and handling properties, silicones often provide the most economical solution to design or application problems. Uses of silicone materials in the electronic industry are discussed.

Luncheon

"Progress and Goals of Our National Society"—Fred C. Sutro, Jr., *SPE National Vice President.*

RETEC Committee

Members of the RETEC Committee are: Chairman: Julius W. Palen, *Lenkurt Electric Co., Inc.;* Program: Kenneth M. Holland, *Hexcel Products, Inc.;* Editing: William G. Hodges, *Wetmore Hodges & Associates, Inc.;* Registration: John J. Bogner, *Chemical Process Co.;* House: Robert S. Elliott, *Owens-Corning Fiberglas Corp.;* Publicity: Frederic M. Rea, *Western Plastics Magazine;* Hospitality: Roland K. Griffith, *Raytherm Corp.;* Treasurer: Robert J. Wnukowski, *Arrow Tool & Die Works;* Financing: John B. Moore, Jr., *Owens-Corning Fiberglas Corp.*

RETEC

Advances in Injection Molding

Sponsored by the Philadelphia Section
Sheraton Hotel, Philadelphia, Pa.
November 6, 1958

Morning Session — 9:30 A.M.

Moderator—Charles W. Kleiderer, *Penn Plastics Corp.*

"Performance Characteristics of Three Designs of Heating Cylinders"—Gustav G. Freygang and R. T. Cassidy, *Rohm & Haas Co.*

The performance characteristics of a Du Pont Polyliner, an IMS Superheater and a Watson-Stillman heating chamber are presented. These characteristics include heating and machine efficiencies, temperature variation of the heated plastics, and temperature ranges over which parts of commercial quality can be made in certain test molds.

"Injection Ram Speed Control in the Molding Process"—Gordon B. Lankton, *Polychemicals Dept., E. I. du Pont de Nemours & Co., Inc.*

A change in injection ram speed can have an important effect on the pattern of mold filling. By using a properly controlled ram speed many molding problems can often be overcome. This paper outlines a method for checking ram speed control and indicates means of maintaining continuous ram speed throughout mold filling.

"A Blow Molding Attachment for Injection Molding Machines"—William H. Chadbourne, *Molding Systems, Inc.*

This paper describes the requirements for and the methods of operating an automatic blow molding attachment for injection molding machines. The equipment allows the injection molder to utilize his present standard equipment for new profits as well as to enter the blow molded container market.

Round Table Discussion—Following the presentation of papers.

Luncheon — 12:30

"Problems of Space Travel" — Logan B. Cowles, *Missile Engineering, General Electric Co.*

"Progress and Goals of our National Society" — Peter W. Simmons, *SPE Past National President:* G. Palmer Humphrey, *SPE National Treasurer:* and Thomas A. Bissell, *SPE Executive Secretary.*

Afternoon Session — 2:30

Moderator—W. J. B. Stokes, III, *Electromold Corp.*

"Engineering of Injection Molded Parts in Business Machines"—Byron W. Nelson, *Plastics Laboratory, National Cash Register Co.*

This paper covers injection molded part design and material selection from the standpoint of both static and functional environments under which it must operate. End use testing plays the most important role in this phase.

"Pre-Compressed Injection Molding Technique" — Albert Spaak, *Polymer Chemicals Div., W. R. Grace & Co.*

This paper covers the advantages of valve gate mold design relative to reduced molding cycles, improved physical properties and quality of the molded part. Also discussed are decreasing scrap losses and reduced finishing costs, reduction in part weight and shrinkage of molded part. Typical gate mold design is shown.

"Mold Design and Fabrication of Polypropylene" — Russell D. Hanna, *Plastics Technical Service Laboratory, Hercules Powder Co.*

Design requirements for molds and molded parts are discussed. Effects on shrinkages and tolerances by material temperatures, machine and tool temperatures and effect of booster pressure and cycle are discussed for Pro-fax polypropylene.

Round Table Discussion—Following the presentation of papers.

RETEC Committee

Members of the RETEC Committee are: Chairman: Edward J. Fitzpatrick, *F. J. Stokes Machine Co.;* Registration: Edward L. Derowski, *Penn Plastics Corp.;* Finance: James R. Hiltner, *Rohm & Haas Co.;* Publicity: Adolph J. Kissileff, *Consultant;* House: George E. Davis, *Electric Storage Battery Co.;* Printing: Albert R. Pollack, *Winner Mfg. Co.;* Program: George L. Graf, Jr., *E. I. du Pont de Nemours & Co., Inc.*

spe

ABOUT MEMBERS

Albert R. McIntyre, National Councilman from the Pioneer Valley Section, is now president of McIntyre Machine Sales Co., Inc., recently formed to handle sales of injection molding machinery and allied equipment in the New England States. He was formerly with Reed-Prentice Corp. **Frederick W. McIntyre, Jr.,** also of the Pioneer Valley Section, is secretary-treasurer of the new firm.

Harold D. Allick, Cleveland-Akron Section, has recently become manager of the plastics department of Goodyear Tire & Rubber Co., Chemical Div. He replaces **Allen E. Polson,** also of the Cleveland-Akron Section, who has resigned from the company. Mr. Allick will be responsible for sales of Pliovic resins. A graduate of Case Institute of Technology, he joined Goodyear in 1952. His most recent position was senior sales engineer. He is also a member of the American Chemical Society, SPI and Alpha Xi Sigma fraternity.

H. D. Allick

L. P. Thies

Lawrence P. Theis has been made district manager for Goodyear Tire & Rubber Co., Chemical Div. He has had previous experience in sales development of synthetic fibers and sales of industrial coatings and vinyl dispersions. Upon joining Goodyear in 1956, he was assigned to the Chemical Division's Cleveland office and later transferred to Detroit as special field representative. Mr. Thies holds a B.S. degree from Kent State University and a master's degree in business administration from Indiana University. He is a member of the Detroit Section of SPE, American Chemical Society, Akron Rubber Group, Detroit Rubber and Plastics Group, and Ontario Rubber Group.

Thomas P. Murphy has been appointed district manager for Fiberfil, Inc., Warsaw, Ind. His territory will include New York and most of the New England States. A member of the New York Section of SPE, Mr. Murphy is a graduate of MIT where he acquired his MA degree. He was formerly associated with Spencer Chemical Co.

Herman I. Silversher of the Southern California Section is joining International Coatings Co., Culver City, as technical director. He was formerly consultant on plastics and adhesives in the Los Angeles area.

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Robert E. Workman, former manager of the Goodyear International Corp., Chemical Div., now holds the recently-created position of assistant general manager of the Goodyear Chemical Div. He has been on leave of absence for the past year while participating in the executive development program at Massachusetts Institute of Technology under a Sloan Fellowship, and was awarded a M.S. degree for his work there. Mr. Workman first joined Goodyear in 1942. A graduate of Case Institute of Technology with a B.S. degree in chemical engineering, he is a member of the Cleveland-Akron Section of SPE, the American Chemical Society, American Institute of Chemical Engineers and Chemical Market Research Association.

R. E. Workman

K. A. Kaufmann

Kenneth A. Kaufman is now supervisor of plastics market research and development at Amoco Chemicals Corp., a newly-created position. Mr. Kaufman comes to Amoco from Spencer Chemical Co. where he was manager of plastics technical service and the sales service laboratory. He obtained his B.Ch.E. degree from Pratt Institute and his M.Ch.E. from Rensselaer Polytechnic Institute. A member of the Chicago Section, he is also active in ASTM and SPI.

John L. Sekowski of the Chicago Section has formed the Seko Tool & Engineering Co., Franklin Park, Ill. The company, of which Mr. Sekowski is president, will specialize in plastics molds including injection, compression and transfer.

Jay D. Sherman, former district manager of the Reed-Prentice branch office in New York City, is now field sales manager of the Reed-Prentice Div., Package Machinery Co., East Longmeadow, Mass. He will supervise the sales force handling the firm's injection molding and die-casting machines in the eight branch offices throughout the country. He is a member of the Newark Section.

Dr. Frank C. McGrew has been named director of a newly-formed Research and Development Division within Du Pont's Polychemicals Dept. **Dr. John S. Beekley** has assumed the position of administrative assistant to the general management of the Polychemicals Dept., and will assist departmental management in formulating technical policies. Other promotions in the Polychemicals Dept. include: **Dr. William E. Grigsby**, director of plastics research and development; **Dr. Daniel E. Strain**, product manager for hydrocarbon polymers; **Dr. D. H. Johnson**, product manager for fluorocarbon polymers; and **Dr. W. H. Linton**, product manager for Delrin acetal resin. All are members of the Philadelphia Section of SPE.

★ ★ ★

RETEC

Plastics Trends in Building and Construction

Sponsored by the Southern California Section

Ambassador Hotel, Los Angeles, Calif.

November 13, 1958

Morning Session

9:00 A.M.—Keynote Address—Thomas A. Bissell, *SPE Executive Secretary*

9:05 A.M.—"House of Tomorrow"—Monsanto Chemical Co. Movie

9:35 A.M.—"Architect's Viewpoint" — Paul Hunter, A.I.A., *Hunter & Benedict Architects*

10:00 A.M. — "Plastics Materials in New Research House"—Ralph Johnson, *National Association of Home Builders*

10:20 A.M.—Coffee Break

10:35 A.M.—New Material Discussions — Moderator: Walter H. Kadlec, *E. I. du Pont de Nemours & Co., Inc.*

"Plastics Flashing Materials" — D. R. Gray, *Dow Chemical Co.*

"Epoxy Pastes and Sealants"—Arthur Heath, *Furane Plastics, Inc.*

"Organic Polymers in Construction Industry"— L. J. Breidenback, *Narmco Resins & Coatings Co.*

"Polystyrene Foam Core Sandwich Panels"—Edwin A. Edberg, *Koppers Co., Inc.*

12:30 P.M.—Luncheon

"Los Angeles—Stone Age to Space Age"—Eugene Weston, *Los Angeles Chamber of Commerce, Building Dept.*

"Progress and Goals of Our National Society"—R. K. Gossett, *SPE National President*

Afternoon Session

2:05 P.M. — Building Code Panel—Moderator to be selected

"Fire and Safety in the Use of Plastics as a Building Construction Material"—Vivian Rapp, *Los Angeles Building Dept.;* Frank X. Ambrose, *Alsynite Corp.;* Joe R. Yockers, *California State Fire Marshall*

2:45 P.M.—Plastics Pipe Panel—Moderator: Martin Usab, *Chemtrol Co.*

"Polyethylene Pipe"—Harold Kotkin, *Plastics Process Co.*

"ABS Pipe"—W. L. Hess, *Plastic Pipe & Tube Corp.*

"PVC Pipe"—Richard Kress, *American Plastic Pipe Co.*

3:30 P.M.—Panel on New Applications to Building Interior—Moderator: George Huisman, *Filon Plastics Corp.*

"Nylon in Building Construction"—T. R. von Toerne, *Allied Chemical Corp.*

"Synthetic Fabrics for Interior Decorators" — H. Grieve, *National President, American Institue of Decorators*

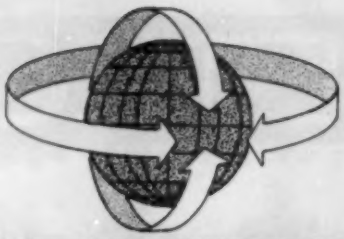
"Plastics in the Lighting Industry"—E. Balogh, *Sunbeam Electric Co.*

* "Plastics Tiles and Sealants"—H. Goodrich, *Gladding McBean Co.*

* "Plastics Panels"—*Filon Plastics Co.*

RETEC Committee

Members of the RETEC Committee are: Chairman: John Delmonte, *Furane Plastics, Inc.;* Publicity: Lloyd Dixon, *Houghton Laboratories, Inc.;* House: Edward M. Lang, *Furane Plastics, Inc.;* Printing: Paul Nielson, *Shell Chemical Co.;* Treasurer: Ray Seymour, *Loven Chemical of California;* Registration: John Shelton, *E. I. du Pont de Nemours & Co., Inc.;* Program: Louis Tallman, *The Dow Chemical Co.;* Ex Officio: Section President Jack Fuller, *Hercules Powder Co.*



PLASTICS AROUND THE WORLD

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GERMANY

DER PLASTVERARBEITER
February, 1958

Abstracter: Leo Fischer

Handling of Synthetics in Eyeglass Frame Production—Herman Redock

The author states that the technique of finishing eyeglass rims is primitive today in comparison to ancient days. Faults in finishing eyeglass rims is the softening of celluloid in hot water or oil. The water or oil permanently enters the material and deterioration sets in. The same is true of acetone. It is advised to use acetone only where polishing tools are inaccessible.

This article will be continued.

The Technique of Extrusion—Jean Peynichon

This is the ninth installment of an extensive treatise on extrusion. This issue deals with heat and temperature control. The author discusses the characteristics of various metals and their sensitivity in heat control instruments. He also explains when to use what type of instrument and how to install it for maximum efficiency.

★

KUNSTSTOFFE
March, 1958

Abstracter: Charles S. Imig

The Interchangeability of PVC Plasticizers—Dr. Ing. K. Stoeckhert

This article points out the comparative uselessness of plasticizer efficiency data published in technical literature. In order to fulfill the need for worthwhile data comparing the relative plasticizing efficiency of the many vinyl plasticizers, most of them are compared by the author in an effort to stimulate discussion. Comparisons are made at plasticizer concentrations of 23 to 40% using DOP as a standard.

Production of PVC Paste Resins by Spray-Drying—Dr. Ing. D. Rysavy

Manufacturing conditions for the production of PVC paste resins were investigated. In spray-drying it was discovered that the temperature of the drying tunnel was the most critical factor. Use of the proper temperature will result in plastisols with better room temperature flow properties. The nature of the particle surface is more important than the particle size. Moisture concentrations of up to 1% did not influence the flow properties of the plastisols.

Analysis of Polyester Resins Using Paper Chromatography—Dipl. Ing. I. Arendt and Dr. H. J. Schenk.

With the complexity of the dibasic acid-glycol systems used in polyesters now, increasing need has been felt for an analytical procedure for identifying these basic components. Such a method is described which removes the acid portion with a cation exchange resin followed by a quantitive separation of each of the glycol components.

The Use of Plastics In Electro-Technical and Precision Construction—K. Rabe

The proper use of plastics facilitates the production of efficient parts and components. In so doing, the part designer must pay close attention to the basic principles of sound mold design to achieve the best results. If the part designer is unfamiliar with mold design and construction he should definitely consult with a mold designer before the design is finalized whether it be compression or injection molding.

Astralon and Its Use In Cartography—Dr. R. Walter and Dr. J. Becke

This vinyl copolymer Astralon is finding more and more applications. Among these is its use in cartography. For this use, a special grade is available which displays dimensional stability, transparency, surface evenness, aging, and corrosion resistance. Also, of advantage are the ease of drawing on the material, ease of engraving and response to photographic processes.

Surface Finishing Operations Applied to Plastic Sheet—Dr. P. Dornbusch

The author described the relationship between printing and embossing. Emphasis is placed on achieving the desired aesthetic quality without overextending production costs.

★

ITALY

MATERIE PLASTICHE
May, 1958

Abstracter: Alfred L. Alk

Characterizing PVC by Means of its Solubility in Acetone—G. Ciampa

The molecular weight distribution of a high polymer strongly determines its electrical and mechanical properties. Solubility and swelling in certain solvents are similarly dependent on molecular weight distribution. The classical but time-consuming determination is by fractional precipitation of the particles from a solvent. The present work had for its object the rapid determination of relative amounts of high and low molecular weights. A small sample is extracted with boiling acetone. Each fraction is dissolved and reprecipitated from cyclohexanone and weighed. High, low and average molecular weights and the Fikentscher K factor can all be calculated and may be used to describe accurately a host of physical properties of the particular polymer.

Welding Thermoplastics by Means of Infra Red Rays—P. Parrini

Welding of films, sheets and solids is briefly described using high frequency, convection and conduction. Infra red welders are manufactured by Societe Francaise d'Applications Techniques Nouvelles, 4 Rue Ber-

ryer, Paris 8. Materials to be welded —polyethylene, PVC, nylon, polyamides—are clamped in position on a resilient base by two parallel metal holders between which a nichrome wire is supported. The heated wire is moved close to the joint for a selected time and a selected temperature. The sheets melt and weld one to the other without pressure and consequent loss of thickness and mechanical strength. Alternatively, the joint may be cut thermally leaving a strong ridge of fused material on each side. Equipment for normal sealing of bags and packages is illustrated.

Physical Properties of Products from Elastomeric PVC—

This is a study of the effects of four types of primary plasticizers in PVC—DOP, DOS, TCP and G-60—at various concentrations. Curves show changes in physical properties with change in plasticizer content. Simple combinations of the four plasticizers give identical curves which lie predictably intermediate to the primary curves.

Improving the Production of Elastomeric PVC Sheeting—P. Mattiotto

This is a discussion of and plea for adoption of standards for PVC sheeting which will carry the seal of the Italian Institute of Plastics.

The CSB Automatic Drum Press for Injection Molding Thermoplastics—

This is a description of the patented CSB press consisting of a horizontally rotating drum on which are mounted up to eight single cavity injection molds not necessarily of the same capacity. The drum revolves in front of an injection mechanism which includes a helical screw preplasticizer. The presses produce from 10 to 35 pieces per minute with maximum weights of 0.5, 1.0, and 1.8 ounces for the three machines listed.

★

FRANCE

INDUSTRIE DES PLASTIQUES MODERNES

May, 1958

Abstracter: Hans Mayer

Plastics in Agriculture—A Trial in Forcing of Growth—F. Buclon

Tests have been run to compare the qualities and results in the greenhousing of crops, using glass, polyethylene and polyvinyl films. The effects on the soil temperature, the amount of ultraviolet and infrared lights transmitted and the effects on the crops themselves are compared.

★

CANADA

CANADIAN PLASTICS

April, 1958

Abstracter: Samuel S. Oleesky

1958 Achievement Award Winners—

This is a graphic description of the plastics products which were awarded prizes as outstanding examples of design, fabrication or initiative in the use of plastics in Canada. It is interesting food for thought and contains some eye-opening illustrations of the ingenuity of our Canadian cousins. It includes everythings from a violin support to a park bench.

New Class of Resins Ideal for Packing—J. W. Hardie

This is the history of development and a tabulation of useful properties

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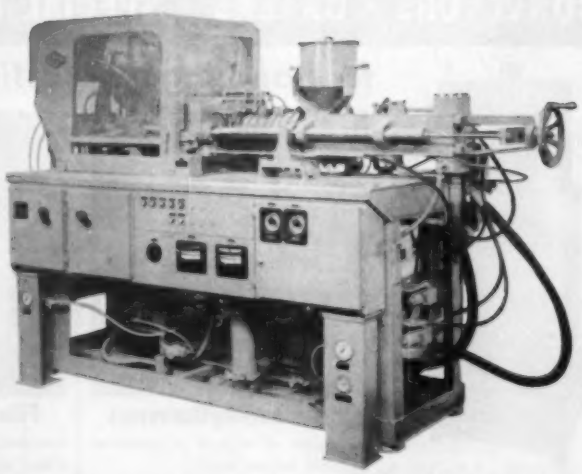

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In Canada, Sherbrooke Machineries Limited, Sherbrooke, Quebec

of Carbide Chemical Company's Polyox high-molecular-weight ethylene oxide polymers. These water-soluble resins are claimed to be ideal for making flexible films. The author meticulously abstains from over-commercializing his paper, and it is almost tutorial in nature. The article is a good introduction to a relatively new material.

★

AUSTRALIA

AUSTRALIAN PLASTICS AND RUBBER JOURNAL
March, 1958

Abstracter: Albert Lightbody

High Temperature Hot Water as a Heating Medium in the Plastics Industry—Leo Walter

The advantages of liquid heat carriers over steam are discussed with emphasis on high temperature water. Temperatures up to 450°F can be achieved with hot water systems at moderate cost. The high pressure of operation is in general the greatest disadvantage. The accuracy of temperature control with steady heat transfer, combined with high heat transfer efficiency, makes the hot water system superior to steam heat transfer systems when a properly designed system is used.

★

UNITED STATES

ASTM BULLETIN
May, 1958

Abstracter: Walter A. Gammel, Sr.

Standards and the New Science of Materials—C. A. Hochwalt

Technologies are being changed at an ever-increasing rate. This is coupled with a higher degree of complexity related to highly-automated processes, new materials and combinations of materials. A new vocabulary is developing. Jet engines are rated, for example, not in horsepower but in "thrust." Materials like Ti_2Cl_3 defy our old concepts of valence. In discussing components for an intercontinental device, "coercivity" and "remanence"—properties—may be more critical than tensile strength; nuclear cross sections in "barns" may be more important than impact strength in foot-pounds.

Tomorrow's standard ideally will give the precise strength at a given temperature and loading rate, dielectric properties at a given frequency, and other data necessary to complete definition of the engineering behavior of the material. Specifications in the future will be indicative not only of quality, but also of engineering performance.

★

MATERIALS IN DESIGN ENGINEERING
April, 1958

Abstracter: Leonard S. Buchoff

Awards Competition for the Best Use of Materials in Product Design—

Plastics figured prominently in many novel redesigns of industrial and consumer products. Butyl rubber is extruded over aluminum conductors in radically new electrical busway. Reinforced polyesters help produce a railway car, which is lightweight and requires very little maintenance. Longer life, improved efficiency, and economy of operation were accomplished by substituting glass-epoxy laminated disc springs for the steel springs in a vibratory feeder.

A liquid fuel rocket nozzle is now

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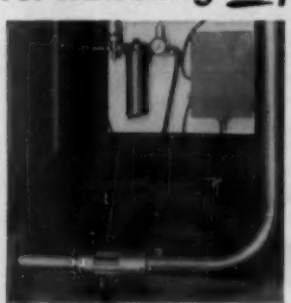

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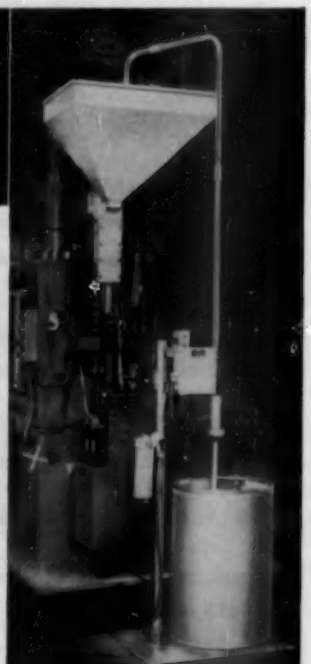

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made by molding a glass reinforced phenolic in place.

Packing composed of polystyrene or polythylene formed sheets increases efficiency of cooling towers. Epoxy-glass prepreg cut weight and cost of aircraft structure. A fastening edge for sandwich panels is made from foamed-in-place urethane, because of its ease of use and compression strength.

The cold flow of Teflon is used to advantage as contact carrier in a resistor box trimmer.

Glass-polyester welding helmets are easier to make and have superior properties to those made of vulcanized fibre. Newly developed "Weatherable Mylar" is used to form an all-weather swimming pool enclosure.

May, 1958

Abstracter: Leonard Buchoff

Water-Thinned Paints—Walter Brenner

Water-thinned paints are used as metal coatings because they are non-flammable, adhere to damp surfaces and eliminate toxicity hazards and the need for solvent recovery systems. In the automobile industry they are being considered mainly as primers.

Styrene-butadiene latices produce the lowest cost water-based paint. They can react to form a thermosetting coating with good adhesion, toughness and hardness. However, impact resistance is comparatively poor.

Polyvinyl acetate metal primers are thermoplastic and so have poor heat resistance. They have good air-drying properties, excellent color retention and resistance to solvents and chemicals.

Water-reduced acrylic coatings are the highest priced of the three. They have outstanding resistance to deterioration, water and salt spray. Resistance to soap solution, detergents and hot water is poor.

★

MECHANICAL ENGINEERING

June, 1958

Abstracter: Philip G. Fleming

Drafting Practice for Plastics—ASME Codes and Standards Workshop—H. E. Minneman

Y14 Section 11, Drafting Practice for Plastics has been approved by the American Society for Engineering Education and the American Society of Mechanical Engineers, sponsors of Y14. The proposed American Standard has been submitted to the American Standards Association for approval. Approval is expected shortly, after which copies will be available.

Section 11, Plastics, should be an aid to designers and draftsmen in the delineation of drawings of plastics parts because it contains the recommended practices of various fabricators. Numerous illustrations have been used in conjunction with the design; drawings hint of those details of molded and laminated parts and assemblies which are normally expected to be incorporated in a product designed by drafting personnel. A brief description of materials and forming processes has been included since their consideration is also required in any design.

Note: Mr. Minneman, Chairman of Y14 Subcommittee 11 has prepared a brief preview of work completed by his subcommittee. When published, this work should be of interest to the plastics industry. Inquiries should be directed to ASME Order Dept., 29 W. 39 St., New York 18, N.Y.

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(Continued on following page)

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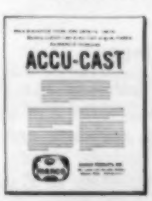

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Classified Ads

(Continued from Page 75)

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★

Sales Engineer

One of America's leading extruder manufacturers needs an experienced sales engineer to be located in the New York-New England ara. This position offers excellent returns to a capable, experienced man. Our employees are advised of this advertisement. Reply Box 4058, SPE Journal, 65 Prospect St., Stamford, Conn.

★

Plastics Designer

Tool and mold. Should have experience in compression and injection molding. Excellent permanent position with large eastern manufacturer. Write in detail to Box 3858, SPE Journal, 65 Prospect St., Stamford, Conn.

POSITIONS WANTED

Production Manager—Extrusion

Fourteen years engineering and managerial experience in extrusion plants. Working knowledge of all extrusion processes and thermoplastics. Heavy experience in polyethylene film and tubing. Have proven ability to plan, organize, motivate and direct action. Reply to Box 3958, SPE Journal, 65 Prospect St., Stamford, Conn.

★

Plastics Chemist-Engineer

Three years experience in organic and synthetic coatings, adhesives all types, and with polyester and epoxy potting operations. Desire position in research and development which would lead to or include sales: Resume available on request. Reply Box 4158, SPE Journal, 65 Prospect St., Stamford, Conn.

Technical Superintendent

Have 15 years' experience in the wire and cable industry. Seek new connection this fall. Proven accomplishments in compounding, dry blend installations, development work, laboratory evaluations and installations, U.L. and Government specifications, plastics engineering in vinyl, Teflon, silicone, polyamide, foamed and irradiated polyethylenes. In touch with latest plastics developments. Excellent references. Willing to relocate. Reply Box 3758, SPE Journal, 65 Prospect St., Stamford, Conn.

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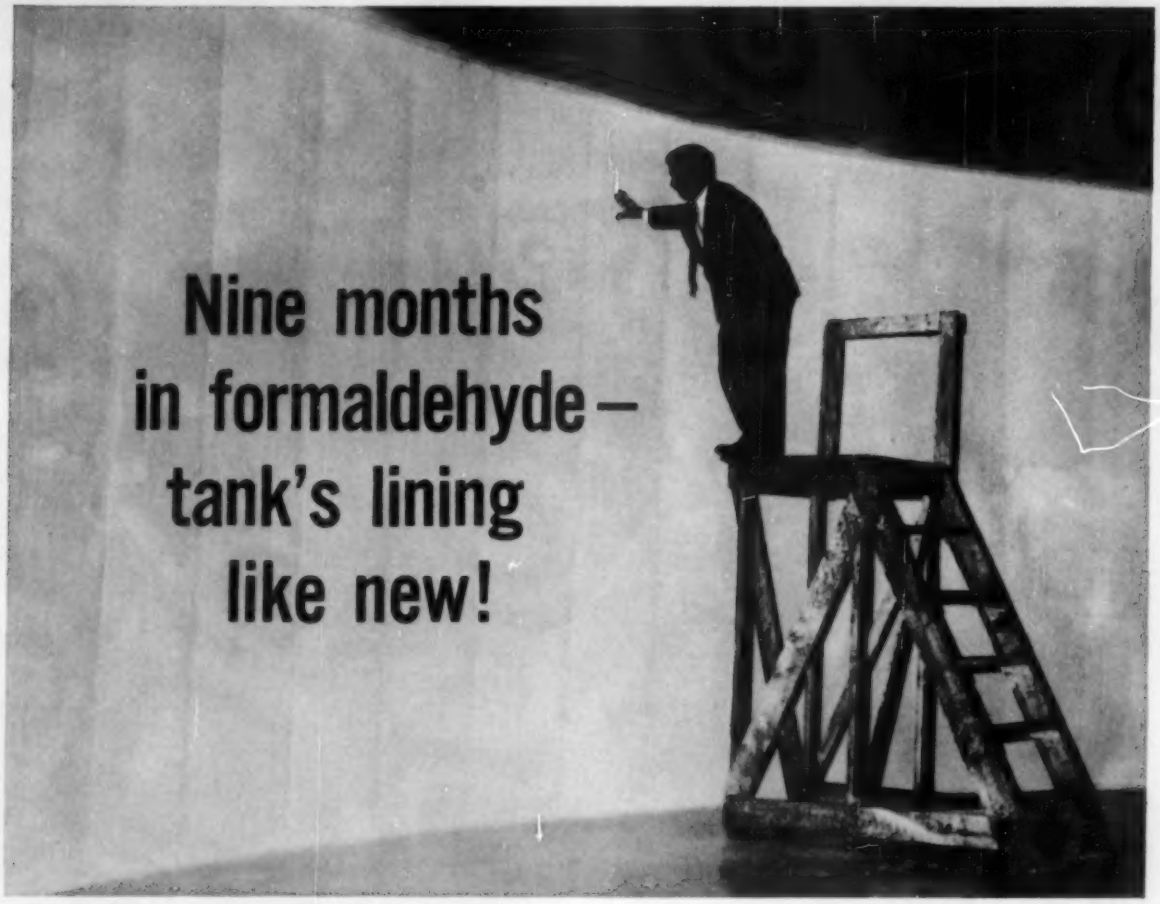
CYANAMID

CORROSIONEERING WITH LAMINAC®

POLYESTER RESINS



Just look at the lining of this 200,000-gallon tank! Nine months in storage service with notoriously corrosive formaldehyde—and not a sign of bleaching, cracking, blistering, pitting or pulling away from the concrete wall!

The lining is glass cloth and LAMINAC Polyester Resin 4109, with a clear finish coat of LAMINAC Resin 4111. It replaced a vinyl-based lining on May 20, 1957. Service life of the original lining had been shortened to the point where the underlying concrete was deteriorating, and contaminating and discoloring the formaldehyde. Yet nine months after installation of the plastic lining, the closest inspection revealed no flaw—not even along the top where it meets the unlined concrete ceiling.

The reinforced LAMINAC lining is expected to last indefinitely. Therefore, a second 200,000-gallon tank will soon be likewise lined with LAMINAC to withstand the corrosive action of the 37% formaldehyde solution kept at 90° F.

If you have a tough corrosion problem, reinforced LAMINAC may well be the answer. For details or technical assistance, get in touch with any Cyanamid office listed below.

AMERICAN CYANAMID COMPANY
PLASTICS AND RESINS DIVISION
32D Rockefeller Plaza, New York 20, N. Y.

CYANAMID Plastics and Resins Division

In Canada: Cyanamid of Canada Limited, Montreal and Toronto
Offices *in:* Boston • Charlotte • Chicago • Cincinnati • Cleveland • Dallas • Detroit • Los Angeles • New York • Oakland • Philadelphia • St. Louis • Seattle

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Plastiatrics

DOW'S CLINICAL APPROACH TO HEALTHY PLASTICS APPLICATION

DOW

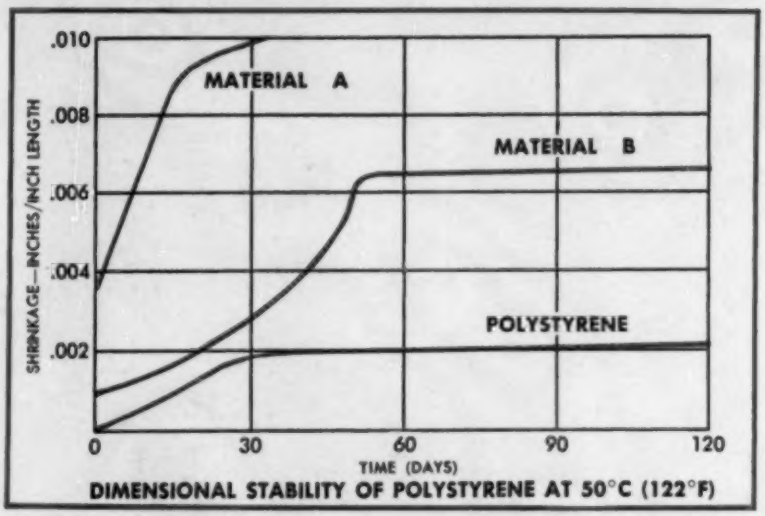
SUPERIOR DIMENSIONAL STABILITY OF STYRON® ASSURES ACCURATE, LASTING FIT

OTHER ADVANTAGES INCLUDE EASY FLOW. HIGH GLOSS FINISH AND HIGH IMPACT STRENGTH

Polystyrene has better dimensional stability than any other thermoplastic material (see chart at right). Even when subjected to elevated temperatures over a period of time, polystyrene retains its dimensional stability better than the two next best materials that could be used.

Styron (Dow polystyrene) is especially suited to molding applications where complex, dimensionally accurate parts are a "must". A case in point is the fan housing shown below. Since both halves of the housing are made from the same mold, dimensional stability is very important. The slightest misfit would detract from the attractiveness of the finished unit. Other reasons for selecting a Styron formulation for this application were its superior impact resistance when tested against an identical metal housing and its high gloss finish.

Styron is available in twelve different formulations which offer a wide range of properties including easy flow, high impact strength, high gloss, and wide choice of colors. If your product can be molded from a polystyrene material, you can be sure a Styron formulation will offer the right combination of properties to mold it properly and economically.



DIMENSIONAL STABILITY OF POLYSTYRENE AT 50°C (122°F)

A continuing series of Plastiatrics studies by Dow Plastics Technical Service Engineers has produced a wealth of information on polystyrene, its dimensional stability, mold shrinkage and thermal expansion. This information is available to you. Address your request for a copy of "Dimensional Tolerances of Polystyrene Moldings" to THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Department 1524F.

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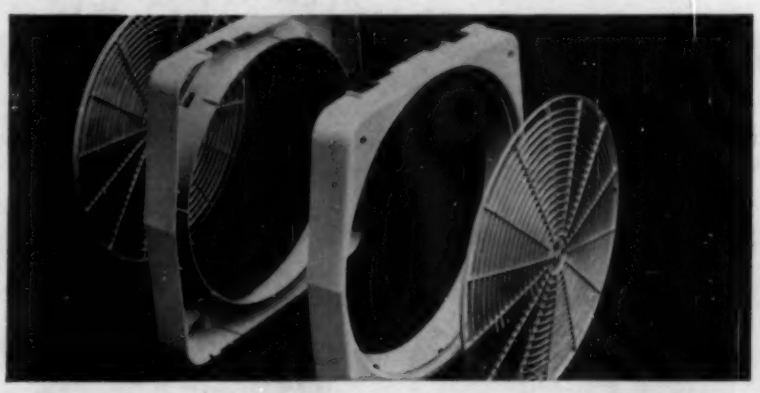
STYRON 440 (Heat Resistant)
STYRON 440M (Easy Flow)
STYRON 480 (Extra-High Impact)

HEAT RESISTANT
STYRON 683
STYRON 700



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